# Runway Excursion During Landing
# Delta Air Lines Flight 1086
# Boeing MD-88, N909DL
# New York, New York
# March 5, 2015


## Accident Report

NTSB/AAR-16/02
PB2016-104166

**National Transportation Safety Board**

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Adopted September 13, 2016

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National
Transportation
Safety Board

490 L'Enfant Plaza, S.W.
Washington, D.C. 20594

**National Transportation Safety Board. 2016.** ***Runway Excursion During Landing, Delta Air Lines Flight 1086, Boeing MD-88, N909DL, New York, New York, March 5, 2015*****. Aircraft Accident Report NTSB/AAR-16/02. Washington, DC.**

**Abstract:** This report discusses the March 5, 2015, accident in which Delta Air Lines flight 1086, a Boeing MD-88 airplane, N909DL, was landing on runway 13 at LaGuardia Airport, New York, New York, when it departed the left side of the runway, contacted the airport perimeter fence, and came to rest with the airplane's nose on an embankment next to Flushing Bay. The 2 pilots, 3 flight attendants, and 98 of the 127 passengers were not injured; the other 29 passengers received minor injuries. The airplane was substantially damaged. Safety issues discussed in the report relate to the use of excessive engine reverse thrust and rudder blanking on MD-80 series airplanes, the subjective nature of braking action reports, the lack of procedures for crew communications during an emergency or a non-normal event without operative communication systems, inaccurate passenger counts provided to emergency responders following an accident, and unclear policies regarding runway friction measurements and runway condition reporting. Safety recommendations are addressed to the Federal Aviation Administration, Boeing, US operators of MD-80 series airplanes, and the Port Authority of New York and New Jersey.

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# Abbreviations and Acronyms

| | |
|---|---|
| **ABS** | automatic brake system |
| **AC** | advisory circular |
| **ACARS** | aircraft communications addressing and reporting system |
| **ACSI** | airport certification safety inspector |
| **agl** | above ground level |
| **ARC** | aviation rulemaking committee |
| **ARFF** | aircraft rescue and firefighting |
| **ARTCC** | air route traffic control center |
| **ASDE** | airport surface detection equipment |
| **ASOS** | automated surface observing system |
| **ATC** | air traffic control |
| **ATIS** | automatic terminal information system |
| **ATL** | Hartsfield-Jackson Atlanta International Airport |
| **CAST** | Commercial Aviation Safety Team |
| **CFME** | continuous friction measuring equipment |
| **CFR** | *Code of Federal Regulations* |
| **CRM** | crew resource management |
| **CUN** | Cancun International Airport |
| **CVR** | cockpit voice recorder |
| **DAB** | Daytona Beach International Airport |
| **EANS** | emergency alert notification system |
| **EPR** | engine pressure ratio |
| **EWR** | Newark Liberty International Airport |

| | |
|---|---|
| **FAA** | Federal Aviation Administration |
| **FDR** | flight data recorder |
| **FOQA** | flight operational quality assurance |
| **IFR** | instrument flight rules |
| **ILS** | instrument landing system |
| **IMC** | instrument meteorological conditions |
| **IND** | Indianapolis International Airport |
| **JFK** | John F. Kennedy International Airport |
| **LGA** | LaGuardia Airport |
| **MSP** | Minneapolis-St. Paul International Airport |
| **NAS** | National Airspace System |
| **NOTAM** | notice to airmen |
| **NTSB** | National Transportation Safety Board |
| **PF** | pilot flying |
| **PM** | pilot monitoring |
| **PNS** | Pensacola International Airport |
| **POI** | principal operations inspector |
| **psi** | pounds per square inch |
| **QAR** | quick access recorder |
| **RCAM** | runway condition assessment matrix |
| **RVR** | runway visual range |
| **SAFO** | safety alert for operators |
| **SB** | service bulletin |
| **SNPRM** | supplemental notice of proposed rulemaking |
| **STL** | Lambert-St. Louis International Airport |

| | |
|---|---|
| **TALPA** | takeoff and landing performance assessment |
| **TRACON** | terminal radar approach control |
| **Vref** | reference landing speed |
| **VOR** | very high frequency omnidirectional radio range |

# Executive Summary


On March 5, 2015, at 1102 eastern standard time, Delta Air Lines flight 1086, a Boeing MD-88, N909DL, was landing on runway 13 at LaGuardia Airport (LGA), New York, New York, when it departed the left side of the runway, contacted the airport perimeter fence, and came to rest with the airplane's nose on an embankment next to Flushing Bay. The 2 pilots, 3 flight attendants, and 98 of the 127 passengers were not injured; the other 29 passengers received minor injuries. The airplane was substantially damaged. Flight 1086 was a regularly scheduled passenger flight from Hartsfield-Jackson Atlanta International Airport, Atlanta, Georgia, operating under the provisions of 14 *Code of Federal Regulations* Part 121. An instrument flight rules flight plan had been filed. Instrument meteorological conditions prevailed at the time of the accident.

The captain and the first officer were highly experienced MD-88 pilots. The captain had accumulated about 11,000 hours, and the first officer had accumulated about 3,000 hours, on the MD-88/-90. In addition, the captain was previously based at LGA and had made many landings there in winter weather conditions.

The flight crew was concerned about the available landing distance on runway 13 and, while en route to LGA, spent considerable time analyzing the airplane's stopping performance. The flight crew also requested braking action reports about 45 and 35 minutes before landing, but none were available at those times because of runway snow clearing operations. The unavailability of braking actions reports and the uncertainty about the runway's condition created some situational stress for the captain, who was the pilot flying.

After runway 13 became available for arriving airplanes, the flight crews of two preceding airplanes (which landed on the runway about 16 and 8 minutes before the accident landing) reported good braking action on the runway, so the flight crew expected to see at least some of the runway's surface after the airplane broke out of the clouds. However, the flight crew saw that the runway was covered with snow, which was inconsistent with their expectations based on the braking action reports and the snow clearing operations that had concluded less than 30 minutes before the airplane landed. The snowier-than-expected runway, along with its relatively short length and the presence of Flushing Bay directly off the departure end of the runway, most likely increased the captain's concerns about his ability to stop the airplane within the available runway distance, which exacerbated his situational stress.

The captain made a relatively aggressive reverse thrust input almost immediately after touchdown. Reverse thrust is one of the methods that pilots use to decelerate the airplane during the landing roll. Reverse thrust settings are expressed as engine pressure ratio (EPR) values, which are measurements of engine power (the ratio of the pressure of the gases at the exhaust compared with the pressure of the air entering the inlet). Both pilots were aware that 1.3 EPR was the target setting for contaminated runways.

As reverse thrust EPR was rapidly increasing, the captain's attention was focused on other aspects of the landing, which included steering the airplane to counteract a slide to the left and ensuring that the spoilers had deployed (a necessary action for the autobrakes to engage). The maximum EPR values reached during the landing were 2.07 on the left engine and 1.91 on the right engine, which were much higher than the target setting of 1.3 EPR. These high EPR values likely resulted from a combination of the captain's stress; his relatively aggressive reverse thrust input; and operational distractions, including the airplane's continued slide to the left despite the captain's efforts to steer it away from the snowbanks alongside the runway. All of these factors reduced the captain's monitoring of EPR indications. The high EPR values caused rudder blanking (which occurs on MD-80 series airplanes when smooth airflow over the rudder is disrupted by high reverse thrust) and a subsequent loss of aerodynamic directional control. Although the captain stowed the thrust reversers and applied substantial right rudder, right nosewheel steering, and right manual braking, the airplane's departure from the left side of the runway could not be avoided because directional control was regained too late to be effective.

Delta issued MD-88/90 fleet bulletins in November 2014 and February 2015 indicating that, for the MD-88, 1.3 EPR was the target setting on runways that are not dry and that 1.6 EPR was the target on dry runways. These targets were also emphasized in revisions to the MD-88/90 *Flight Crew Training Manual*. The November 2014 bulletin further stated that, according to line check data, "many pilots accept reverser settings far below the target." However, the National Transportation Safety Board (NTSB) evaluated flight data from Delta MD-88 airplanes and found other flights that involved maximum EPR levels above those targets. Unlike the accident flight, none of those flights resulted in any adverse outcomes. Because the EPR exceedances were likely the result of human factors issues associated with the high workload during landing operations, flight crews at other air carriers that operate MD-80 series airplanes might also experience such exceedances.

The NTSB identified the following safety issues as a result of this accident investigation:

- **Use of excessive engine reverse thrust and rudder blanking on MD-80 series airplanes.** The NTSB's evaluation of flight data from Delta MD-88 airplanes showed that, despite company training and procedures on EPR targets, more than one-third of the landings captured by the data involved an EPR value of 1.6 or above, indicating the need for strategies to preclude excessive EPR use that could lead to rudder blanking. Such strategies, which could benefit all pilots of MD-80 series airplanes, include (1) identifying industry-wide best practices that have been shown to be effective in reliably preventing EPR exceedances during actual high-workload and high-stress operating conditions, (2) implementing a procedure in which the pilot monitoring would make a callout whenever reverse thrust power exceeded an operator's EPR settings, and (3) exploring the possibility that an automated alert could help flight crews avoid EPR exceedances.

- **Subjective nature of braking action reports.** Even though the flight crew received two reports indicating that the braking action conditions on the runway were good, postaccident simulations showed that the braking action at the time that the accident airplane touched down was consistent with medium (or better) braking action. The flight crew's landing performance calculations indicated that the airplane could not meet the requirements for landing with braking action that was less than good, but the flight crew proceeded with the landing based on, among other things, the reports indicating good braking action on the runway.

  As part of its investigation of the 2005 Southwest flight 1248 accident at Chicago Midway International Airport, the NTSB issued safety recommendations to the Federal Aviation Administration (FAA) that addressed runway surface condition assessment issues, including the inherently subjective nature of pilot braking action reports. One recommendation—to outfit transport-category airplanes with equipment that routinely calculates, records, and conveys the airplane braking ability required and/or available to slow or stop the airplane during the landing roll and develop related operational procedures—has not yet been implemented because these systems are still under development and evaluation. The NTSB continues to encourage the FAA to develop the technology for these systems because they are expected to provide objective, reliable, real-time information that flight crews of arriving airplanes could use to understand the extent of runway surface contamination.

- **Lack of procedures for crew communications during an emergency or a non-normal event without operative communication systems.** Damage to the airplane during the accident sequence resulted in the loss of the interphone and public address system as methods of communication after the accident. As a result, the flight attendants in the aft cabin left their assigned emergency exits to obtain information from the flight crew and the lead flight attendant in the forward cabin. Also, the lead flight attendant left her assigned emergency exit to check on a passenger in the mid-cabin. However, because the airplane was not at a normal gate location or a normal attitude, an emergency evacuation was possible, but the flight attendants were not in a position to immediately open their assigned exits if necessary. Delta's flight attendant manual and training curriculum did not address communicating during an emergency or a non-normal situation without operative communication systems. In addition, Delta did not have guidance instructing flight attendants to remain at their assigned exits during such a situation.

- **Inadequate flight and cabin crew communication, coordination, and decision-making regarding evacuations for an emergency or a non-normal event.** Postaccident interviews with the flight attendants indicated that the captain did not convey a sense of urgency to evacuate the cabin. The first officer stated, during a postaccident interview, that emergency response personnel requested, and the captain subsequently commanded, the evacuation. Postaccident videos provided by a passenger showed that the lead flight attendant announced the plans to evacuate about 6 minutes after the airplane came to a stop. The videos also showed that the flight attendants were confused about the timing of the evacuation, which did not begin until about 6 minutes after the evacuation announcement. In addition, the videos showed that more than 17 minutes had elapsed between the time that the airplane came to a stop and the time that all of the passengers were off the airplane.

The NTSB has a long history of investigating accidents involving inadequate evacuation communication, coordination, and decision-making and has made numerous safety recommendations, including requests for joint evacuation exercises for flight and cabin crews, to resolve these issues. However, FAA efforts to fully address the issues have so far been insufficient. A multidisciplinary effort that focuses on analyzing data involving airplane evacuations and identifying ways to improve flight and cabin crewmember performance could be an effective way to resolve recurring evacuation-related issues.

- **Inaccurate passenger counts provided to emergency responders.** After the accident, the passenger count provided by the flight and cabin crews to air traffic control personnel and emergency responders (125) did not fully reflect the total number of passengers (127) aboard the airplane because two lap-held children were not included in the total passenger count. Delta reported the actual number of passengers to LGA airport operations staff several hours after the accident. However, flight and cabin crews involved in an accident or incident should be able to provide emergency responders with an accurate passenger count (including lap-held children) upon exiting the airplane and without contacting company personnel for further information.

- **Unclear policies regarding runway friction measurements.** LGA and other airports operated by the Port Authority of New York and New Jersey were not using continuous friction measuring equipment (CFME) to assess runway friction after snow removal operations. However, LGA's *Airport Certification Manual* and Port Authority's letter of agreement with the LGA air traffic control tower stated that airport operations staff used CFME to conduct friction assessments when conditions either required trend analysis or might result in degraded runway surface friction. As a result, Port Authority's policies regarding CFME use during winter operations need clarification, especially given that the FAA promotes CFME as a valuable tool for airport operators to detect trends in runway conditions during winter operations.

- **Unclear policies regarding runway condition reporting.** According to the FAA's advisory circular (AC) on airport winter safety and operations, notices to airmen (NOTAM) describing runway surface conditions must be "timely" and need to be updated any time a "change to the runway surface condition" occurs. However, the NOTAM that was current at the time of the accident had been issued 2 hours beforehand, and a new NOTAM was not issued after runway snow clearing operations had completed (27 minutes before the accident). If the FAA clarified the guidance in the AC to specifically describe what constituted a "timely" NOTAM and what types of "change to the runway surface condition" needed to be reported, airport operations personnel could issue more effective NOTAMs, and flight crews could have more updated information regarding runway surface conditions.

The NTSB determines that the probable cause of this accident was the captain's inability to maintain directional control of the airplane due to his application of excessive reverse thrust, which degraded the effectiveness of the rudder in controlling the airplane's heading. Contributing to the accident were the captain's (1) situational stress resulting from his concerns about stopping performance and (2) attentional limitations due to the high workload during the landing, which prevented him from immediately recognizing the use of excessive reverse thrust.

As a result of this investigation, the NTSB makes safety recommendations to the FAA, Boeing, US operators of MD-80 series airplanes, and the Port Authority of New York and New Jersey.

# 1. Factual Information

## 1.1 History of Flight

On March 5, 2015, at 1102 eastern standard time, Delta Air Lines flight 1086, a Boeing MD-88, N909DL, was landing on runway 13 at LaGuardia Airport (LGA), New York, New York, when it departed the left side of the runway, contacted the airport perimeter fence, and came to rest with the airplane's nose on an embankment next to Flushing Bay.[1] The 2 pilots, 3 flight attendants, and 98 of the 127 passengers were not injured; the other 29 passengers received minor injuries. The airplane was substantially damaged. Flight 1086 was a regularly scheduled passenger flight from Hartsfield-Jackson Atlanta International Airport (ATL), Atlanta, Georgia, operating under the provisions of 14 *Code of Federal Regulations* (*CFR*) Part 121. An instrument flight rules (IFR) flight plan had been filed. Instrument meteorological conditions (IMC) prevailed at the time of the accident.

The accident occurred on the second day of a 4-day trip for the flight crewmembers. They reported for duty on the day of the accident at 0500 at Daytona Beach International Airport (DAB), Daytona Beach, Florida. The first leg of the trip departed DAB at 0557, with the captain as the pilot flying (PF) and the first officer as the pilot monitoring (PM), and arrived at ATL at 0705.

Delta's terminal forecast for LGA, which was issued at 0719, was provided to the captain at the departure gate for the flight from ATL to LGA. The forecast for the time of arrival included wind from 330º at 12 knots, visibility 1/2 mile in moderate snow and mist, and ceiling broken at 700 feet above ground level (agl).[2] The forecast also indicated that moderate snow was expected to continue during the morning, with a snowfall accumulation of 4 to 7 inches by 1200. In addition, the flight crew obtained automatic terminal information system (ATIS) reports for LGA via the aircraft communications addressing and reporting system (ACARS).[3]

The accident flight departed for LGA about 0924 with a planned en route flight time of 1 hour 30 minutes.[4] Although the first officer had expected to be the PF for this flight leg

[1] All times in this report are eastern standard time. All miles in this report are expressed in nautical miles except for visibility, which is expressed as statute miles. All altitudes in this report are expressed as mean sea level unless otherwise indicated.

[2] The weather package that Delta provided the flight crew (generated at 0740) also included a notice to airmen (NOTAM) issued at 0445, which stated that the runways were wet and had been sanded and deiced with solid chemical. A NOTAM issued at 0738 (which was not part of the weather package) reported that runway 13 was covered with thin, wet snow.

[3] ATIS information Lima, issued at 0751, and ATIS information Mike, issued at 0851, indicated that all runways were wet and had been sanded and chemically treated. ATIS information Lima reported 1/4-mile visibility. ATIS information Mike reported 1/2-mile visibility in snow and freezing fog, a temperature of -2º C (28º F), and an overcast ceiling at 1,400 feet agl. The remarks section indicated that the tower visibility was 3/4 mile.

[4] The flight was originally scheduled to depart for LGA at 0845, but the departure was delayed because of a needed repair to the captain's oxygen mask.

(because the captain had been the PF for the first flight leg of the day), the captain decided to be the PF because of the anticipated poor weather conditions. During the flight, the pilots continued to monitor the weather conditions at LGA.

According to the cockpit voice recorder (CVR), at 0954:52, the flight crew began discussing the initial approach into LGA. At that time, the airplane was in cruise flight at an altitude of 33,000 feet. The first officer stated, "I doubt we'll hear [a braking action report of] medium poor but we're at our crosswind limitations for that one."[5] At 0955:05, the captain asked the first officer to contact the company dispatcher, via ACARS, for a field condition report. The report from the dispatcher indicated that braking action advisories were in effect; taxiways were reported to have 3-foot snowbanks along their edges; and runways were reported to be wet, sanded, and deiced with solid chemical.

At 1005, the flight crew discussed the effect of moderate snow on visibility. Beginning at 1010:35, the flight crew discussed the landing distance using flaps 40, a 130,000-pound landing weight, and medium/fair braking action. The flight crew consulted the MD-88 *Operational Data Manual* and determined that, according to the forecasted conditions for LGA, a braking action report of "good" was needed for the airplane to meet Delta's guidance to safely land on runway 13.[6] The captain stated, "we can't land" with medium/fair braking action, and the first officer agreed, indicating that, with maximum autobrakes or maximum manual braking, the calculated landing distance would be 7,800 or 7,200 feet, respectively, which would exceed the runway 13 available length of 7,003 feet. The crew's discussion continued, and the captain stated at 1015:36, "if it's [the braking action] less than good we're not landing," to which the first officer responded, "roger that—I don't blame you one bit."

About 1018, the flight crew sent the dispatcher the following message: "Need braking action reports for LGA. We can only land with good. Anything less than that we are over weight." The dispatcher replied, "I'll pass the braking action along as soon as I get one…Port Authority is presently working on rwy 13." About that time, the captain noted that the latest ATIS did not include any braking action reports.[7]

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[5] Delta's crosswind guidance limited the crosswind component to 10 knots if braking action was medium/poor.

[6] Delta's *Operational Data Manual* data were advisory in nature and provided flight crews with a means to assess an airplane's landing performance. The data included a 1,500-foot air distance, credit for using reverse thrust, and a safety factor of 15%. According to these data, a wet runway was considered to have good braking action. The MD-88 quick reference chart for operational landing distances described good braking action as normal braking deceleration for the wheel braking effort applied and normal directional control.

[7] ATIS information Oscar, issued at 0951, reported the wind from 030º at 10 knots, 1/4-mile visibility in snow and freezing fog, an indefinite ceiling at 1,200 feet agl, and a temperature of -3º C (27º F). The ATIS also reported that all runways were wet, sanded, and deiced with solid chemical and that braking action advisories were in effect. Federal Aviation Administration (FAA) Order 7110.65, "Air Traffic Control," stated the following about braking action advisories: "when runway braking action reports are received from pilots or the airport management which include the terms 'fair,' 'poor,' or 'nil' or whenever weather conditions are conducive to deteriorating or rapidly changing runway conditions, include on the ATIS broadcast the statement 'Braking Action Advisories are in effect'." The order instructed controllers, whenever braking action advisories were in effect, to "issue the latest

At 1024:57, a controller at Washington Air Route Traffic Control Center (ARTCC) advised the flight crew to hold at the Robbinsville VOR while LGA personnel performed "runway clean up."[8] The first officer acknowledged this information. Afterward, the captain expressed disappointment to the first officer that the dispatcher had not previously notified them that LGA arriving airplanes were holding. At 1027:35, the controller asked the flight crewmembers if they would be able to fly the instrument landing system (ILS) approach to runway 13 at LGA. The first officer replied, "depends on braking action…do you have reports for us?" The controller stated that she did not have any braking action reports and then restated the question about whether the flight crew would be able to fly the ILS approach to runway 13. The first officer stated that "we can certainly do the ILS to [runway] one three...but we need braking action reports. We're trying to get them from dispatch as well." At 1037, the flight crew sent an ACARS message to the dispatcher expressing surprise that runway 13 was closed and asking the dispatcher why he had not provided that information to the crew.

At 1042:10, the Washington ARTCC controller cleared the flight to continue toward LGA and then instructed the flight crew to descend to 10,000 feet and switch the frequency to the New York Terminal Radar Approach Control (TRACON). After the frequency change, the captain briefed the ILS approach to runway 13 and then instructed the first officer to complete the descent checklist. At 1045:38, the CVR recorded the approach controller advising Delta flight 1526 (an MD-88) that he had just received a report of poor braking action. The accident captain said to the accident first officer, "we can't land with poor." Afterward, the approach controller asked the flight crews of Delta flight 1526 and Envoy Air flight 3647 (a CRJ-701) whether they would be able to land with poor braking action; both crews replied "negative."

At 1047:02, the approach controller advised Envoy flight 3647 that an Airbus 319 airplane had just completed its landing rollout and reported that braking action was good.[9] A pilot of the Envoy flight stated, "we can take it then." The controller then asked if Delta flight 1526 had heard the latest braking report, and a pilot of that flight stated, "braking action good is good for us." At 1050, the dispatcher replied to the flight crew's 1037 ACARS message, indicating that runway 13 "is not closed" and that the pilots of a United Airlines flight that had just landed (the Airbus 319 airplane referenced by the controller) reported good braking action.

At 1052:51, the approach controller alerted all aircraft on the frequency that ATIS information Quebec was current.[10] The ATIS information indicated a visibility of 1/4 mile with

braking action report for the runway in use to each arriving and departing aircraft early enough to be of benefit to the pilot."

[8] A VOR (very high frequency omnidirectional radio range) is a navigational aid.

[9] The Airbus model was not identified in the controller's transmission but was later identified (during the investigation of this accident) as an A319. The A319 landed about 1046, 16 minutes before the accident airplane touched down.

[10] ATIS information Quebec included the following information: wind from 030º at 11 knots, indefinite ceiling at 900 feet agl, temperature -3º C (27º F), dew point -5º C (23º F), and altimeter setting 30.12 inches of mercury.

snow and freezing fog, but the runway visual range (RVR) at the time was 6,000 feet.[11] The ATIS information also indicated that "all runway field conditions 1/4 inch wet snow observed at 1404Z [0904 local]" and that "all runways are wet and have been sanded and deiced with solid chemical."[12] At 1054:41, the first officer told the controller, while acknowledging heading and airspeed instructions, "we have Quebec." At 1055:34, the captain stated, "wonder who reported braking action good? That's another concern of mine," and the first officer replied that "it was United." At 1057:38, the approach controller announced to all aircraft on the frequency that a "regional jet reported braking action good," and the first officer repeated to the captain, "RJ [regional jet] good."

The approach controller vectored the flight to intercept the final approach course at an altitude of 3,000 feet and, at 1058:41, cleared the flight for the ILS approach to runway 13. At 1059:12, the controller instructed the flight to contact the LGA tower and reported that the RVR was greater than 6,000 feet with a rollout RVR of 4,000 feet. At 1059:30, Delta flight 1526 landed; the pilots did not report the braking action (and the controller did not request this information). In a postaccident statement, the flight crew of Delta flight 1526 indicated that the braking action on runway 13 was good.

At 1059:24, the first officer of the accident flight contacted the LGA tower, and the local controller cleared the flight to land. At 1059:54, the captain told the first officer to "ask [the controller] one more time for a wind check. I'm showing a pretty good tailwind here. Eleven knots."[13] At 1100:32, the controller reported that the wind was from 020º at 10 knots, to which the captain stated "geez." The flight crew added 5 knots to the 131-knot reference landing speed ($V_{ref}$) because of the wind.[14]

The ILS approach to runway 13 had a decision altitude of 214 feet (based on a height of 200 feet above the touchdown zone). At 1101:51, the captain called the approach lights in sight (at an altitude of 335 feet agl) and, 2 seconds afterward, stated "we're gonna continue" (which was not a required callout). The captain called the runway in sight 8 seconds later (at an altitude of about 233 feet agl). During postaccident interviews, the captain and the first officer stated that they did not expect to see (after the airplane broke out of the clouds) a runway that was all white and apparently covered with snow.

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[11] RVR is a measurement of the horizontal distance that a pilot should be able to see down a runway from the approach end. The normal minimum visibility required for the runway 13 ILS approach was 1/2 mile or an RVR of 2,400 feet. At 1040:13, the Washington ARTCC controller informed another flight crew that the RVR for runway 13 was 6,000 feet; immediately afterward, the accident first officer stated to the accident captain, "six thousand."

[12] This information was also included in ATIS information Papa, which was a special weather observation issued at 1024. At 1042:34, the first officer told the approach controller "we have Papa."

[13] During a postaccident interview, the captain stated that, while on final approach, he monitored the flight management system's wind display, which initially indicated that the airplane was encountering a 10- to 11-knot direct tailwind but then indicated a quartering tailwind.

[14] Delta's MD-88/90 *Flight Crew Training Manual* noted the following: "Do not apply wind additives for tailwinds. Set command speed at VREF + 5 knots (autothrottle engaged or disconnected)." The autothrottle was disconnected at an altitude of 188 feet agl.

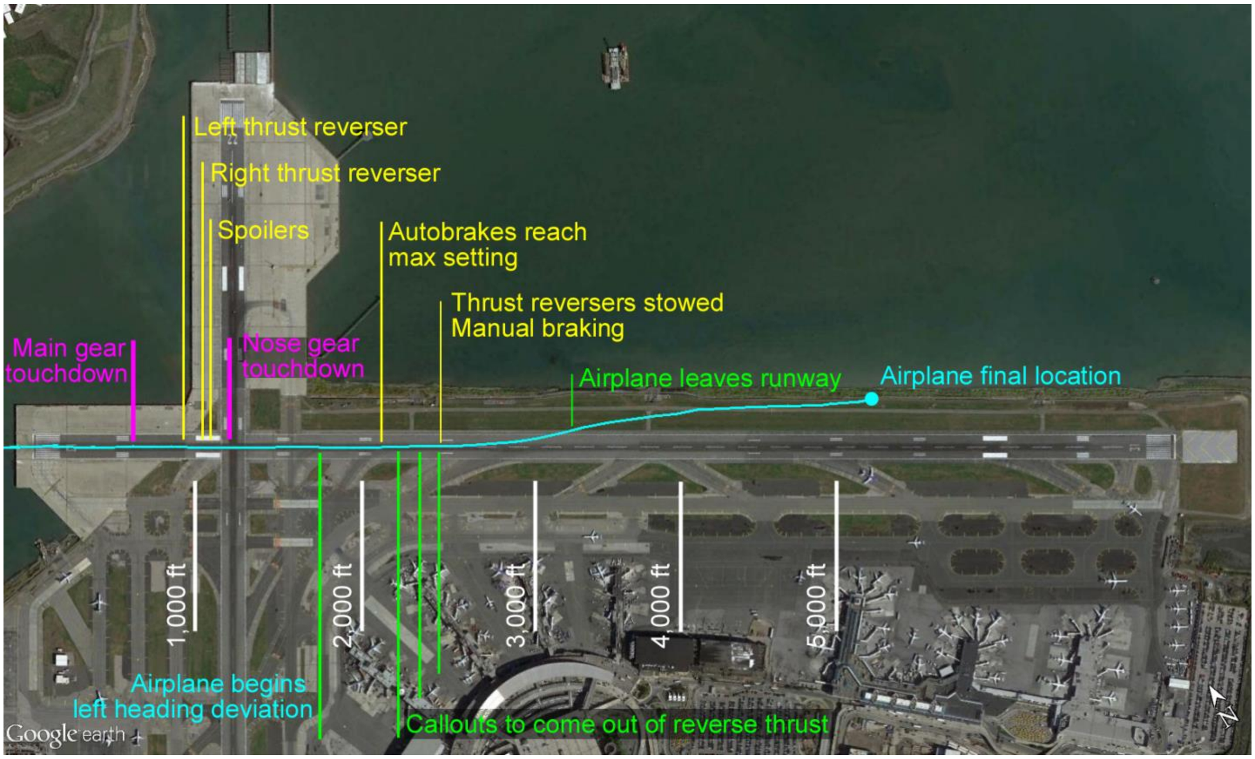
According to the flight data recorder (FDR), the airspeed during final approach was about 140 knots. The airplane crossed the runway 13 threshold at an airspeed of 137 knots, and, at 1102:16, the main gear touched down 600 feet from the threshold at an airspeed of 133 knots (a groundspeed of 140 knots).[15] The airplane's heading at the time was about 132º; the runway 13 magnetic heading was 134º. At 1102:17.5, the thrust reversers deployed. The first officer stated, during a postaccident interview, that the spoilers did not automatically deploy, so he manually deployed them; the CVR showed that, at 1102:19, he announced "spoilers up." At 1102:21, the first officer stated "two in reverse," referring to the thrust reversers, and then called out an airspeed of 110 knots. About 1.5 seconds later, the first officer stated "out of reverse"; immediately afterward, he stated "come out of reverse" and then repeated his statement in a louder voice. Table 1 shows events pertaining to the deployment of braking devices during the landing roll, and figure 1 shows these events overlaid on an image of runway 13.

**Table 1.** Timeframe of events after main gear touchdown.

| Event | Time | Elapsed time after main gear touchdown (1102:16) |
|---|---|---|
| Thrust reverser deployment | 1102:16.5 to 1102:17.5 | 0.5 to 1.5 seconds |
| Spoiler deployment | 1102:16.5 to 1102:17.5 | 0.5 to 1.5 seconds |
| Autobrake deployment (maximum) | 1102:17.8 to 1102:18.8 | 1.8 to 2.8 seconds |
| Nose gear touchdown | 1102:18.7 to 1102:19.7 | 2.7 to 3.7 seconds |
| First officer's callout "two in reverse" | 1102:20.9 | 4.9 seconds |
| First officer's callout "one ten" | 1102:22.2 | 6.2 seconds |
| First officer's statement "out of reverse" | 1102:23.7 | 7.7 seconds |
| First officer's statement "come out of reverse." | 1102:24.5 | 8.5 seconds |
| Manual braking | 1102:24.9 to 1102:25.9 | 8.9 to 9.9 seconds |
| First officer's repeated statement "come out of reverse." | 1102:25.2 | 9.2 seconds |

**Note:** The FDR parameters listed in this table were sampled once per second. As a result, the times for the deployment of the braking devices and nose gear touchdown were specified as a 1-second range during which the event occurred.

[15] Main gear touchdown corresponded with a spike in the FDR vertical acceleration data. Surface movement radar data from LGA showed that the airplane touched down within 5 feet of the runway centerline and that the airplane did not deviate from the centerline by more than ±5 feet until 2,300 feet from the runway threshold (1,700 feet and 8 seconds after main gear touchdown).




**Note:** The background image does not depict the environmental conditions on the day of the accident.

**Figure 1.** Runway location of events after main gear touchdown.

During a postaccident interview, the captain stated that, as he was lowering the airplane's nose to the ground after main gear touchdown, he moved the thrust reversers to idle and then "one knob width on the reverser handle" to obtain Delta's target setting of 1.3 engine pressure ratio (EPR).[16] FDR data showed that engine reverse thrust exceeded 1.3 EPR between 3 and 4 seconds after main gear touchdown (with the left engine exceeding 1.3 EPR before the right engine) and was advancing through 1.6 EPR immediately after the nose gear touched down. FDR data showed that the EPR value exceeded 1.6 for 5 seconds, reaching maximum EPR values of 2.07 on the left engine and 1.91 on the right engine between 6 and 7 seconds after main gear touchdown. Engine power decreased after this point, and the thrust reversers were stowed at 1102:25 (7.5 seconds after deployment, 9 seconds after main gear touchdown, and 2,500 feet from the runway threshold) at an EPR value of 1.8 on the left engine and 1.6 on the right engine. At that time, the airplane's groundspeed was 93 knots.

[16] EPR is a measurement of engine power as a ratio of the pressure of the gases at the exhaust compared with the pressure of the air entering the inlet. Delta's MD-88/90 *Flight Crew Training Manual*, dated October 23, 2014, stated that, during landings on wet or slippery runways, reverse thrust should be applied "smoothly and symmetrically" to 1.3 EPR and cautioned that reverse thrust above 1.3 EPR could degrade directional control effectiveness. The landing distances in Delta's *Operational Data Manual* included the use of 1.3 EPR reverse thrust for runways that are not considered to be dry.

FDR data showed that brake pressure began to increase, consistent with autobrake application, within 2.8 seconds after main gear touchdown, which was just before the nose gear touched down.[17] Autobrake pressure began decreasing to 0 psi 8 seconds after the initial pressure increase, which occurred about the same time as the thrust reversers were stowed. Afterward, the right brake pressure increased, consistent with manual application of the right brake and autobrake disengagement.

At 1102:22, 6 seconds after main gear touchdown and 1,600 feet from the runway threshold, the airplane began to deviate to the left of the runway's 134º magnetic heading (in response to a left yaw rate), reaching a heading of 114º 6 seconds later.[18] FDR data showed that, as the airplane was deviating to the left, the rudder position reached a peak of 23º to the right.

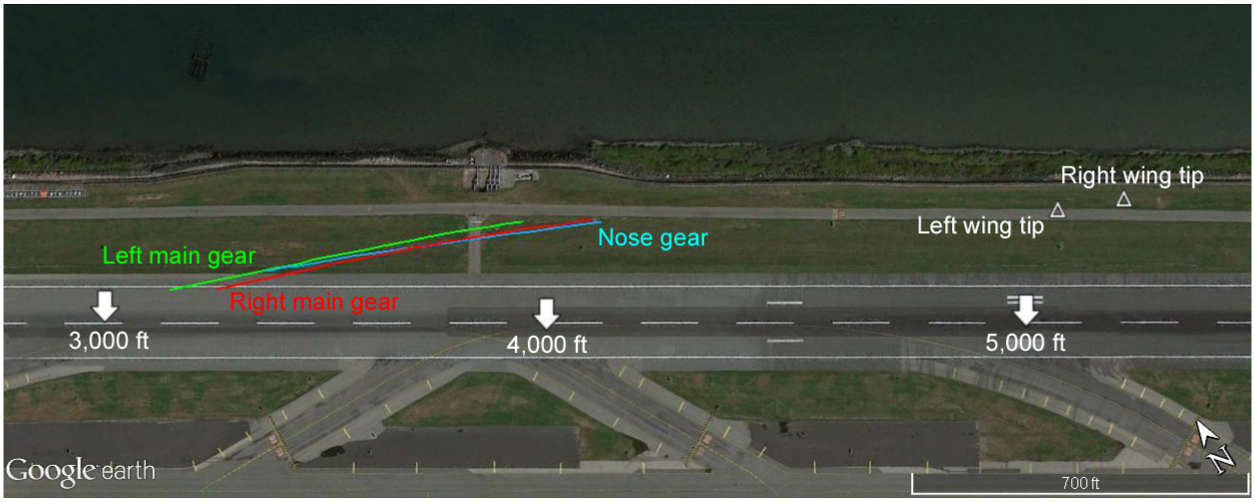
Despite the application of right rudder and right braking, the airplane continued to yaw to the left and departed the left side of runway 13 about 1102:30. Ground marks and surface movement radar data from LGA showed that the airplane departed the runway 3,200 feet from the runway threshold.[19] During a postaccident interview, the first officer stated that the airplane continued to slide and that the left wing contacted and became caught on a retaining wall for Flushing Bay. (The CVR recorded "scraping" sounds between 1102:43 and 1102:52.) At that point, the first officer shut down the engines to prevent any further thrust from pushing the airplane into Flushing Bay.[20] The captain stated the airplane's nose broke through a fence on the wall and that both he and the first officer could see the water below the cockpit as the airplane came to a stop. Figure 2 shows the location of the ground marks for the left, right, and nose gear and the location where the airplane came to rest (as indicated by the labels for the left and right wings), and figure 3 shows the airplane at its resting location.

[17] The full pressure available using maximum autobrakes was 3,000 pounds per square inch (psi).

[18] The captain made rudder inputs to counter the left yaw rate that preceded the heading change, as discussed further in section 1.8.1.

[19] By 1102:32, the airplane's heading had moved back to the right, reaching 125º before the FDR magnetic heading parameter became invalid, as discussed further in section 1.6.

[20] FDR data indicated that the engines were shut down at 1102:53. The CVR stopped recording at 1102:54. The CVR transcript appears in appendix B.




**Note:** The background image does not depict the environmental conditions on the day of the accident.

**Figure 2.** Ground marks and airplane location.


**Source:** Delta Air Lines.

**Note:** Several pieces of the perimeter fence and support posts are shown.

**Figure 3.** Photograph of the accident airplane on an airport berm.

During a postaccident interview with the FAA, the local controller stated that he saw the airplane pass through the intersection of runway 13 with runway 4 but did not see (because of the weather conditions) the airplane's departure from runway 13 or the location where the airplane came to rest. The controller also stated that he did not observe the airplane's data information drop from the airport surface detection equipment (ASDE-X) radar display because he was "focusing on the next arrival [Delta flight 1999] who was checking in on [the local control] frequency at that time."[21] The controller indicated that he attempted to contact the accident flight crew six times and, after receiving no response, assumed that the airplane had "cleared onto the non-movement area without contacting [ground control]."

The airplane's main batteries were damaged during the accident sequence, resulting in a lack of power to the electrical systems before the engines were shut down. The first officer stated that he attempted, but was unable, to switch on the emergency power and start the auxiliary power unit. As a result, the flight and cabin crews were unable to communicate using the interphone or the public address system.[22]

The captain exited the flight deck and asked the lead flight attendant to assess the exits.[23] The first officer used his cell phone to call company dispatch, which transferred the call to the LGA tower about 1110. The first officer reported the number of persons aboard (125 passengers and 5 crewmembers) and the fuel quantity.[24] The flight crew conducted those parts of the evacuation checklist that could be done without power. According to the first officer, a firefighter approached the window on the first officer's side of the cockpit and told him (through a partially opened window) that everyone should evacuate the airplane via the right overwing exits due to fuel leaking from the left wing. The first officer relayed this information to the captain, who then told the flight attendants to begin evacuating the passengers from the right overwing exits and the tailcone exit.[25] The evacuation and emergency response are further discussed in section 1.7.

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[21] At 1104:33, the controller instructed the flight crew of Delta flight 1999 to go around.

[22] The interphone allows the pilots to communicate with the flight attendants (and vice versa), and the public address system allows the flight and cabin crews to communicate with passengers about information related to a flight, including evacuation instructions if necessary. The four interphones installed on the accident airplane were located in the cockpit, at the 1L and 2L doors, and at the tailcone exit.

[23] The time between the airplane coming to a stop and the captain exiting the flight deck could not be determined because the CVR had stopped recording. Also, videos provided by a passenger after the accident (see section 1.7.1) did not contain that information.

[24] The first officer referenced the passenger count that was provided on the final weight and balance report, which the pilots received via ACARS. As previously stated, 127 passengers were aboard the airplane. The discrepancy between the initially reported and actual number of passengers is discussed in section 1.7.1.

[25] The captain reported that a firefighter told him during the evacuation to use the tailcone exit in addition to the right overwing exits. The flight attendants reported that they did not know about the fuel leak until after the evacuation was already underway.

## 1.2 Personnel Information

### 1.2.1 The Captain

The captain, age 56, held an airline transport pilot certificate with a multiengine land rating and an FAA first-class medical certificate dated January 5, 2015, with a limitation that required him to wear corrective lenses for near and distant vision. (The captain reported that he was wearing glasses during the flight.) The captain received a type rating for DC-9 type airplanes on January 31, 2001.[26] The captain also received a type rating for the Boeing 757 and 767 on April 28, 1997, and a flight engineer rating for the Boeing 727 on October 13, 1989. He reported flying the Boeing 767 and 727 for Delta before the MD-88 and MD-90.

The captain had been employed at Delta since August 1989. Before then, he was an F-16 pilot and a T-38 instructor with the US Air Force. According to a postaccident interview with the captain and Delta flight records, the captain had accumulated about 15,200 hours total flight time, including about 11,000 hours in the MD-88 and MD-90 and about 9,700 hours as pilot-in-command. He had flown 702, 165, 56, and 3.8 hours in the 12 months, 90 days, 30 days, and last duty period, respectively, before the accident. The captain's last line check occurred on November 12, 2014, and his last recurrent ground training occurred on November 18, 2014. FAA records indicated no accident or incident history or enforcement action, and a search of records at the National Driver Register found no history of driver's license revocation or suspension. The captain was based at ATL, and he stated that he flew into LGA about three times per month. The captain had previously been based at LGA.

During postaccident interviews, a Delta pilot who had flown with the captain stated that he was professional, current on policies and procedures, and standardized in handling the airplane. An instructor pilot recalled that the captain was well prepared for training, was experienced, and worked well with people. A Delta first officer stated that the captain was prepared, careful, and calm and that he followed standard operating procedures.

**72-Hour History**

On March 2, 2015, the captain was off duty. He recalled exercising, engaging in routine activities at home, and going to sleep at 2330 or 2400. On March 3, the captain was also off duty. He recalled waking about 0700, volunteering, exercising, engaging in routine activities at home, and going to sleep at 2100.

On March 4, 2015, the captain woke at 0400 for work. Company records indicated that he reported for duty at 0625 and that he and the first officer flew three legs between 0721 and

[26] According to Boeing, the MD-88 was part of the MD-80 series of airplanes, which, along with MD-90 series airplanes, were variants of the DC-9. Delta operates both the MD-88 and MD-90. The MD-90 is slightly longer than the MD-88 and has different engines.

1327.[27] The captain then went to a hotel, exercised, and had dinner with the first officer. The captain recalled returning to the hotel at 1800 and going to sleep about 2100. He also recalled waking "a couple of times" during the night for no particular reason but reported that he was able to quickly fall back to sleep.

On March 5, 2015, the captain woke at 0340. He described his quality of sleep as "okay" but stated that he felt rested that morning. Table 2 shows the captain's sleep schedule during the 72 hours preceding the accident.

**Table 2.** The captain's self-reported sleep schedule.

| Date | Bedtime | Awakening time | Sleep opportunity |
|---|---|---|---|
| March 2 to 3 | 2330 or 2400 | 0700 | 7 to 7.5 hours |
| March 3 to 4 | 2100 | 0400 | 7 hours |
| March 4 to 5 | 2100 | 0340 | 6 hours 40 minutes |

### 1.2.2 The First Officer

The first officer, age 46, held an airline transport pilot certificate with a multiengine land rating and an FAA first-class medical certificate dated July 14, 2014, with no limitations. The first officer received a type rating on DC-9 type airplanes on March 9, 2011. The first officer also received a type rating for the Boeing 737 on November 15, 2007 (second-in-command privileges only) and a flight engineer rating for the Boeing 727 on June 18, 2001. He reported flying the Boeing 737 for Delta for 3 1/2 years before flying the MD-88 and MD-90.

The first officer had been employed at Delta since September 2007. Before then, he was a Boeing 727 flight engineer with another 14 *CFR* Part 121 operator and an E2C Hawkeye pilot with the US Navy. According to a postaccident interview with the first officer and Delta flight records, the first officer had accumulated about 11,000 hours total flight time, including about 3,000 hours in the MD-88 and MD-90. He had flown 671, 184, 64, and 3.8 hours in the 12 months, 90 days, 30 days, and last duty period, respectively, before the accident. The first officer's last line check occurred on August 9, 2013, and his last recurrent ground training occurred on January 10, 2015. FAA records indicated no accident or incident history or enforcement action, and a search of records at the National Driver Register found no history of driver's license revocation or suspension.

During a postaccident interview, a captain who had flown with the first officer stated that he had good interaction skills and that he was "very comfortable" flying and "very capable." Another captain who had flown with the first officer stated that he was "very skilled."

[27] The first flight departed ATL at 0721 and arrived at Indianapolis International Airport (IND), Indianapolis, Indiana, at 0851. The second flight departed IND at 0935 and arrived at ATL at 1115. The third flight departed ATL at 1205 and arrived at DAB at 1327. The captain stated that these flights were uneventful.

**72-Hour History**

On March 2, 2015, the first officer was off duty. He recalled spending time with his family, engaging in routine activities around the house, and going to sleep about 2200. The first officer reported receiving a call about 2 hours later offering him a 1-day trip on March 3, which he accepted.

On March 3, 2015, the first officer woke about 0500. He recalled that his quality of sleep was "fine." The first officer reported for duty at 0630. He had been scheduled to fly from ATL to Pensacola International Airport (PNS), Pensacola, Florida; have a layover at PNS for 6.5 hours; and then fly a return leg to ATL. Because the leg to PNS had been rescheduled, the first officer deadheaded (that is, flew as a nonrevenue passenger) to PNS and flew to ATL as second-in-command, arriving at 1700. He arrived home at 1900 and went to sleep at 2200.

On March 4, 2015, the first officer woke at 0440. He could not recall the quality of his sleep but thought that it was "probably fine." Company records indicated that the first officer reported for duty at 0625 and that, as previously stated, he and the captain flew three legs between 0721 and 1327. The first officer recalled that, after arriving at the hotel, he took a nap, relaxed, and exercised. He recalled having dinner with the captain at 1630, returning to his room between 1830 and 1900, and going to sleep about 2030.

On March 5, 2015, the first officer woke at 0410. He recalled that his quality of sleep was "excellent" and stated that he felt rested. Table 3 shows the first officer's sleep schedule during the 72 hours preceding the accident.

**Table 3.** The first officer's self-reported sleep schedule.

| Date | Bedtime | Awakening time | Sleep opportunity |
|---|---|---|---|
| March 2 to 3 | 2200 | 0500 | Less than 7 hours |
| March 3 to 4 | 2200 | 0440 | 6 hours 40 minutes |
| March 4 to 5 | 2030 | 0410 | 7 hours 40 minutes |

**Note:** The first officer's sleep period during the night of March 2 to 3 was interrupted by a company scheduling call (of unknown duration) at midnight on March 3.

## 1.2.3 The Flight Attendants

Flight attendant 1, age 60, was the flight leader (a flight attendant specifically trained in the duties and responsibilities of a purser or a lead flight attendant). She had been employed at Delta since October 1977. In June 2008, she qualified as a flight leader. Her last recurrent training occurred on February 13, 2015. She was off duty on March 4, 2015, but commuted from West Palm Beach, Florida, to ATL that day so that she could be ready for the flight to LGA the next day. (The accident flight was the first leg of a 3-day trip for all of the flight attendants.) During the accident flight, she occupied the jumpseat at the main cabin door (1L).

Flight attendant 2, age 38, had been employed at Delta since February 2014. She had also been employed at Delta as a flight attendant from November 1998 to December 2006, during which time she qualified as a flight leader. Her last recurrent training occurred on August 25,

2014. She was off duty on March 4, 2015. During the accident flight, she occupied the jumpseat at the 2L door.

Flight attendant 3, age 49, became an employee of Delta when the company and Northwest Airlines merged. She had been employed at Northwest Airlines as a flight attendant since August 1990. Her last recurrent training occurred on August 14, 2014. She completed a trip on March 4, 2015, and had 12 hours of rest between that trip and the next day's trip. During the accident flight, she occupied the aft tailcone jumpseat.

## 1.3 Airplane Information

The accident airplane, serial number 49540, was manufactured in July 1987 and was delivered new to Delta in December 1987. At the time of the accident, the airplane had 71,196 total flight hours and 54,865 total flight cycles.[28] The airplane was equipped with two Pratt & Whitney JT8D-219 turbofan engines, which were mounted to the aft fuselage. The No. 1 engine had accumulated 61,336 total hours and 45,859 total cycles, and the No. 2 engine had accumulated 50,308 total hours and 37,609 total cycles.

Airplane maintenance records showed that, during the 6 months preceding the accident, the 600-flight hour, 2,200-flight hour, and 760-day inspections were completed with no discrepancies. The 760-day inspection focused on, among other things, autoflight, flight controls, hydraulics, landing gear (brakes, antiskid, and autobrakes), engine power, and thrust reversers. The most recent tire pressure check was performed on the day of the accident, and the most recent transit check and service check were completed 3 days before the accident; no discrepancies were noted during these checks. The electronic airplane data logs showed no open items related to the flight controls, engines, landing gear, or brakes.

### 1.3.1 Thrust Reverser System

Each engine has a thrust reverser connected to the aft section of the engine. The thrust reversers are controlled by levers (handles) hinged to each of the engine throttles on the center pedestal in the flight deck and are operated when a flight crewmember rotates the levers through 120º of movement. When operated, the thrust reverser levers deploy and stow the reversers and control engine thrust. The thrust reverser control system levers (at the throttle quadrant) can only be operated when the throttles are in their idle position.[29] Reverse engine thrust cannot be commanded until the thrust reversers are fully deployed, but the thrust reverse levers can be fully stowed before reverse engine thrust is at idle. Each thrust reverser has two doors, one attached to the upper engine fairing and one attached to the lower engine fairing, and two thrust reverser door actuators. When extended, the doors change the direction of fan air and exhaust gas flow to

[28] An airplane cycle is one complete takeoff and landing sequence.

[29] The throttles are moved forward to increase thrust and pulled back to decrease thrust. Each throttle connects to its respective engine fuel control assembly.

help decelerate the airplane.[30] An amber "reverse unlock" light illuminates when a thrust reverser is unlatched, and a blue "reverse thrust" light illuminates when a thrust reverser is fully extended. Both lights are located at the top of the engine display panel (located on the center instrument panel).

The thrust reverser settings are expressed as EPR values. The EPR gauges (also on the engine display panel) provide a digital readout in the center of each gauge of the EPR value, as shown in figure 4. Around the circumference of each gauge is a dial with incremental markings for EPR values between 1.0 and 2.2. A digital yellow pointer moves around the circumference of the gauges to provide a visual indication of both forward and reverse thrust values, but the engine display panel shows the EPR limit only for forward thrust.

On June 14, 1996, McDonnell Douglas Corporation published a service bulletin (SB) regarding the installation of a newly designed thrust reverser cam with an intermediate detent that would correspond to a value of about 1.3 EPR.[31] McDonnell Douglas later indicated that two operators had difficulty rigging the mechanical engine control system to the 1.3 EPR value at the detent, which prevented "repeatable matched reverse thrust EPR" from being obtained on each engine during operations. As a result, on April 7, 1997, McDonnell Douglas issued a message recommending that operators remove the cam with the intermediate detent and replace it with an original cam that had no detent. The company issued a corresponding SB on May 29, 1997.

In 1980, McDonnell Douglas issued a flight test report (which was updated in 1984) about the ground-handling characteristics of MD-80 series airplanes, including lateral controllability at high reverse thrust EPR values. The report indicated that, because the engines on MD-80 series airplanes are mounted alongside the tail, high reverse thrust greatly reduces the directional control authority of the rudder, which was referred to as "blanking" the rudder (McDonnell Douglas Corporation, 1980).

On November 5, 2002, Boeing issued Flight Operations Bulletin MD-80-02-03, "Reverse Thrust EPR Control." According to Boeing, the bulletin reiterated information in the company's MD-80 *Flight Crew Operating Manual* about rudder blanking. The bulletin stated the following:

> Due to the geometry of the MD-80 thrust reversers, the exhaust gas efflux pattern will, at certain rollout speeds and EPR settings, interfere with the free-stream airflow across the rudder surfaces. This will result in partial "*rudder blanking*"; with a resultant reduction in directional control authority. As rudder effectiveness is more critical on wet or slippery surfaces, "*rudder blanking*" becomes a concern above a reverse thrust level of 1.3 EPR. Normal dry runway maximum reverse thrust power is 1.6 EPR [emphasis in original].

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[30] MD-80 series airplanes have "bucket- type" thrust reversers. When the thrust reversers are stowed, fan air and exhaust gas flow exit the engines from their outflow sections. When the thrust reversers are extended, the two doors move aft, rotate, and connect to direct the fan air and exhaust gas flow forward (the reverse direction) above and below the engines and away from the engines' air intake.

[31] McDonnell Douglas and Boeing merged in August 1997.

**Source:** Delta Air Lines.

**Figure 4**. Engine pressure ratio gauges on engine display panel.

McDonnell Douglas' flight test report also included the results of testing regarding the effects of airspeed and reverse thrust EPR on the rudder. According to the report, the testing indicated that the rudder had limited directional authority when in reverse thrust with (1) an EPR value above 1.3 and an airspeed below 108 knots and (2) an EPR value above 1.6 and an airspeed below 146 knots (McDonnell Douglas Corporation, 1980). The report included a graph that noted "1.6 EPR controllable down to 146.5 knots" and "1.3 EPR controllable down to 108 knots."

### 1.3.2 Braking System

The MD-88's braking system includes manual and automatic brakes (autobrakes), which are located on the main landing gear. Manual brakes are applied using the brake pedals in the flight deck. Autobrakes are applied after an airplane touches down if (1) the autobrake system is armed (using a toggle switch on the autobrake control panel, which is located on the aft right side of the center pedestal) and (2) a deceleration rate for the landing roll—minimum (MIN), medium (MED), or maximum (MAX)—is selected (using a rotary switch on the autobrake control panel). The autobrakes deploy after spoiler deployment and with the throttles pulled back to decrease thrust. The automatic brake system (ABS) targets and then maintains a constant level of deceleration, and a flight crew can override the ABS at any time and revert to manual brake operation by pressing the brake pedals.[32]

During the landing roll, the ABS uses only the airplane's right hydraulic system, but both the left and the right brakes receive equal brake pressure. The ABS also receives information from the antiskid control system about the airplane's deceleration (derived from wheel speed) compared with the selected deceleration rate.[33] The ABS then modulates brake system pressure (with a hydraulic land manifold) to maintain the selected rate of deceleration. The MIN position has a deceleration rate of 4 ft/sec$^2$, and the MED position has a deceleration rate of 6.5 ft/sec$^2$. In the MAX position, full right brake hydraulic system pressure (3,000 psi) is applied to the brakes, and the maximum deceleration rate is limited by the antiskid system (to regulate the amount of hydraulic pressure on each wheel and prevent a skid) and the runway friction (tire/pavement interface). Delta's MD-88/90 *Flight Crew Training Manual*, page 6-15, dated January 16, 2014, stated that, if autobrakes are to be used during a landing on a wet or a slippery runway, pilots should consider selecting the MAX setting.

### 1.3.3 Spoiler System

The MD-88 has one ground spoiler, one inboard flight spoiler, and one outboard flight spoiler on each wing. The inboard flight spoiler actuators are powered by the left hydraulic system. The outboard flight spoiler actuators are powered by the right hydraulic system. The ground spoiler actuators are powered by both hydraulic systems.

The flight spoilers can be manually operated through the aileron control system by either the control wheel or the speedbrake control lever (spoiler handle) on the forward pedestal. A

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[32] The ABS has two modes of operation: landing and takeoff. The takeoff mode is used during rejected takeoffs.

[33] The antiskid system adapts braking pressure to runway conditions by sensing an impending skid condition and adjusting the brake pressure on each individual wheel to allow for maximum braking performance.

control wheel input can supplement lateral control by extending the flight spoilers on one wing to a maximum of 60º from the faired position. The speedbrake lever extends the flight spoilers symmetrically on both wings to a maximum of 35º in flight and a maximum of 60º on the ground. When the flight spoilers are not extended, they are mechanically held in the retracted position by a spring-loaded torsion bar.

The ground spoilers can be manually operated by a mechanical input from the speedbrake control lever (once the airplane is on the ground) and require an electrical signal from main wheel spin-up and ground-sensing relays. The ground spoilers are extended to about 60º during landing (or a rejected takeoff) and are locked down by hydraulic power and a mechanical overcenter link during all other phases of flight.

The flight and ground spoilers can be automatically operated during landing (or a rejected takeoff) by the autospoiler system. To use the system for landing, a pilot raises the speedbrake control lever to the ARM position, which reveals a red ARM indicator stripe and positions the roller on the speedbrake lever in front of the autospoiler crank arm. When commanded, an autospoiler actuator moves the crank arm from the retracted to the extended position, and the crank arm moves the speedbrake lever fully aft to extend the spoilers.[34]

### 1.3.4 Postaccident Examination of N909DL

During the on-scene examination of the airplane, 20 components were removed from the airplane for subsequent testing. These airplane components were from the brake, spoiler, and nosewheel steering systems; the flight data acquisition unit; the proximity switch electronics unit; and the enhanced ground proximity warning system. During the testing, no evidence was found of a system failure or a malfunction that could have led to the loss of directional control, caused the airplane to exit the side of the runway, or prevented the flight crew from returning the airplane to the intended groundpath.[35]

The engines were not tested after the accident, but continuity of the controls was established for both engines with no faults or visible damage noted. Examination of the thrust reverser system and its components found no anomalies. The thrust reversers were operated successfully during a postaccident actuation exercise conducted in the maintenance hangar that housed the airplane after the accident.[36] Specifically, the thrust reversers, when actuated with the

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[34] The autospoiler actuator is electrically controlled by an autospoiler switching unit. During landing, the unit commands autospoiler actuator extension (and spoiler deployment) with main wheel spin-up. In the absence of main wheel spin-up, autospoiler actuator extension occurs automatically with nose strut compression via the nose oleo switches.

[35] Although faults were found during the testing of some of these components, the faults were determined to be either typical of in-service components that had been exposed to normal operation or unrelated to the primary operation of the component during the critical portions of the approach, landing, and rollout.

[36] During this exercise, hydraulic power and limited electrical power were applied to the airplane's hydromechanical systems to actuate the airplane's thrust reversers, manual brakes, and flight controls and determine their operation.

thrust reverser levers on the left and right throttles, deployed normally both together and separately and then retracted normally.

During the postaccident actuation exercise, manual brake application was accomplished with no anomalies noted. Examination of the airplane's autobrake and antiskid systems found that the airplane's brakes and tires functioned normally with no indications of preaccident faults that would have affected the airplane's ability to stop on the runway. Also, no excessive wear was noted on the tire treads and brakes, each of the brake wear indicator pins exhibited sufficient brake wear, and each of the gear axle antiskid sensors was undamaged and rotated freely.

Examination of the spoiler system components found no faults or failures that would have prevented the spoilers from activating immediately upon landing. During the examination, the spoilers and autospoiler actuator activated with no noted anomalies. During the postaccident actuation exercise, the inboard and outboard flight spoilers deployed normally in response to spoiler handle movement. The ground spoilers deployed normally (with full travel to their up position) when the left and right hydraulic systems were pressurized.

No preimpact discrepancies were found in the aileron, elevator, or rudder flight control systems. During the postaccident actuation exercise, the rudder trim tab and the elevator boost cylinders were actuated, and the rudder and elevator surfaces moved as commanded from the rudder pedal and the control column, respectively. No issues were noted with either control system.

The left wing fuel tank was found breached near a hinge attachment point for the left outboard trailing edge flap. During the on-scene examination, fuel was observed dripping from the area of the breach. The on-scene examination also found the trailing edge flaps set at 40º, which was consistent with the flight crew's flap selection. The leading edge slats, leading edge flaps, and trailing edge flaps all measured at actuations consistent with a 40º setting. The actuations were consistent across both wings and with FDR data.

## 1.4 Meteorological Information

LGA has an automated surface observing system (ASOS) that is augmented by a National Weather Service-certified weather observer. At 1100 (2 minutes before the accident), the ASOS reported wind from 030º at 9 knots, visibility 1/4 mile, moderate snow and freezing fog, vertical visibility 900 feet agl, temperature -3º C (27º F), dew point -5º C (23º F), and altimeter 30.12 inches of mercury.[37]

The ASOS observations on the day of the accident indicated that snow mixed with rain began at 0326 and that light snow began at 0412. An observation at 0651 noted that 3 inches of snow was already on the ground from previous storms. At 0657 moderate snow began. The observation at 0751 noted 1 inch of new snow and a total of 4 inches of snow on the ground; the

[37] Vertical visibility is the vertical distance that can be seen into a surface-based obscuration.

observation 1 hour later noted another inch of new snow and a total of 5 inches of snow on the ground. At the time of the accident, 3 inches of new snow, and a total of 6 inches of snow, was reported on unprotected areas, and snow was falling at a rate of about ¾ inch per hour.[38]

## 1.5 Airport Information

LGA is located about 8 miles east of Manhattan in the borough of Queens. The airport has an elevation of 21 feet and borders Flushing Bay and Bowery Bay. LGA has two runways, 4/22 and 13/31, which were extended over water to their present length and width in 1966. Runway 13/31 has a grooved concrete surface and is 7,003 feet long and 150 feet wide. LGA is operated by the Port Authority of New York and New Jersey. The FAA's annual airport certification inspection reports for LGA for 2013 through 2015 showed no deficiencies related to winter operations.

### 1.5.1 Airport Snow Operations on the Day of the Accident

LGA snow removal personnel and equipment were divided into five color-coded teams, including the blue team, which was assigned to clear runway 13/31; the red team, which was assigned to clear east-side taxiways; and the amber team, which was assigned to clear high-speed taxiways.[39] LGA also had a snow coordinator, who oversaw the five snow removal teams and was responsible for making observations of snow type and depth on the airport's surfaces. Those observations were then published as NOTAMs.

On March 4, 2015, the LGA airport manager and operations staff met at 1800 regarding the weather forecast and predicted snowfall for the next day. They decided to activate the highest level of snow operation readiness at LGA as of 0600 on March 5. During the overnight hours of March 5 (0000 to 0600, when LGA was regularly closed for air traffic operations), the runways and taxiways were treated with solid chemicals and sanded in advance of the expected snowfall. The field condition report issued at 0444 indicated wet runway conditions, and the report at 0557 indicated no snow accumulation on the paved surfaces. A NOTAM issued at 0738 indicated that runway 13 was covered with thin, wet snow. Airport measurements showed that, by 0851, 1.8 inches of snow had fallen, and NOTAMs issued at 0902 and 0903 (for runways 4/22 and 13/31, respectively) indicated that 1/4 inch of wet snow was on the runways. Airport measurements also showed that, by 0951, another 1/2 inch of snow had fallen.

[38] The official snow amounts reported in the observations may differ from the snow amounts that LGA operations staff reported (based on measurements taken by contract weather observers at the airport) due to the reporting criteria used. Section 1.5.2 provides information about the LGA-reported snowfall.

[39] The snow removal teams operated multifunction vehicles with a 26-foot plow to push accumulated snow to the right side of a runway or taxiway, a 26-foot broom to sweep any residual snow after plowing, and a blower on the back of the vehicle to move snow toward a runway or taxiway edge.

At 1006, the blue team was cleared by the local controller to proceed onto runway 13/31 for snow removal operations.[40] The team made two and one-half clearings (with a complete clearing being up and down a runway) and exited the runway at 1035 so that landings could resume. Three minutes later, the local controller asked the LGA snow coordinator about the "official" runway conditions. The snow coordinator, who was traveling with the blue team, responded, "we're advertising with the NOTAMs a quarter inch of wet snow and snow banks up to a foot...and the runways have not been treated. We're just brooming and plowing."[41] During a postaccident interview, the LGA snow coordinator stated that the snow removal teams were not applying chemical to the runways once snow began to accumulate because any application of chemical "would have been broomed right off."

After runway 13/31 had been cleared, four airplanes landed on runway 13 ahead of the accident airplane. Table 4 provides information about each of the landings, including the reported braking action (if provided) at the touchdown zone.

**Table 4.** Landings on runway 13 after snow clearing operations.

| Flight information | Airplane model | Approximate time of landing | Time before accident landing | Reported braking action at touchdown zone |
|---|---|---|---|---|
| United Airlines flight 462 | A319 | 1043:27 | 18 min 53 sec | Medium |
| United Airlines flight 694 | A319 | 1046:04 | 16 min 16 sec | Good |
| Envoy Air flight 3647 | CRJ-701 | 1053:57 | 8 min 23 sec | Good |
| Delta Air Lines flight 1526 | MD-88 | 1059:30 | 2 min 53 sec | Not provided or requested |
| Delta Air Lines flight 1086 | MD-88 | 1102:20 | N/A—accident flight | N/A—accident flight |

**Note:** The approximate time of landing was based on ASDE-X video data. The flight crew of Delta flight 1526 reported, after the accident, that the braking action on runway 13 was good.

Although the flight crew of United Airlines flight 462 initially reported that the braking action was medium, the crew also reported that the braking action was "poor down here where we're coming off at [taxiway] Mike." (This report was the poor braking action referenced by the controller at the New York TRACON.) Afterward, the flight crew of United Airlines flight 694 reported that the braking action near taxiway M was good. Nevertheless, the amber team made a complete pass of the taxiway immediately after the flight 694 airplane cleared the area.

According to snow measurements at LGA, between 0951 and 1051 (11 minutes before the accident landing), 0.4 inch of snow had fallen, for a total of 2.7 inches at the airport.[42] Between 1051 and 1151 (49 minutes after the accident landing) another 0.7 inch of snow had fallen, for a total of 3.4 inches.

[40] LGA's aeronautical operations manager stated that a decision to begin plowing operations was based on braking action reports, visual inspections, weather forecast data, and surface temperatures.

[41] The snow coordinator was referring to the NOTAMs issued at 0902 and 0903. No additional NOTAMs were issued before the accident.

[42] Snow measurements at LGA were made by the Marine Air Terminal. According to Port Authority, the Marine Air Terminal comprises FAA contractors with various disciplines in the field of meteorology. The contractors use a thin metallic ruler provided by their weather service to measure the snow hourly and as requested.

### 1.5.2 Runway Condition Reports

During a postaccident interview, the LGA chief operations supervisor stated that airport operations staff did not routinely issue updated field condition reports after each runway clearing and that updated reports would only be issued if the previously reported conditions had changed. He also stated that, before the accident landing, the snow was “a thin covering” on the runway that “at no point [was] above a quarter of an inch.” He thought that keeping the 0903 NOTAM in place (which indicated that 1/4 inch of wet snow was on runway 13/31) was “being conservative” and “safer” than reporting a “thin covering” of snow before arriving airplanes began to land on the cleared runway. LGA’s airport operations manager, who agreed with the chief operations supervisor’s position, stated that he would rather report that a runway has 1/4 inch of snow than report that the runway’s “blacktop” can be seen, which could put an airplane “in harm’s way.” LGA’s aeronautical operations manager added, “when we’re out there in snow conditions plowing, brooming, we’re going to keep [the snow accumulation] down to the condition that the NOTAM was initially issued for…as long as we do that, that NOTAM stays [in effect].”

On December 9, 2008, the FAA issued Advisory Circular (AC) 150/5200-30C, “Airport Winter Safety and Operations,” to provide information to assist airport operators in developing a snow and ice control plan, conducting runway friction surveys and reporting the results, and establishing snow removal and control procedures.[43] The AC stated the following regarding the reporting of runway conditions: “because runway surface conditions can change quickly, either due to weather conditions or corrective actions taken to mitigate such conditions, NOTAMs describing the runway surface conditions must be *timely* [emphasis in original].” The AC advised airport operators to review their snow and ice control plan procedures to ensure that they were “conducive to timely reporting.”[44]

The AC also stated, “runway condition reports must be updated any time a change to the runway surface condition occurs. Changes that initiate updated reports include weather events, the application of chemicals or sand, or plowing or sweeping operations.” The AC further stated that “airport operators should not allow airplane operations on runways after such activities until a new runway condition report is issued reflecting the current surface condition(s) of affected runways.”

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[43] Although most ACs are advisory in nature, the cover page of AC 150/5200-30C showed that all airports certificated under 14 *CFR* Part 139 were required to comply with all sections of the AC. According to the FAA, the means of compliance did not have to follow the AC. Version C of the AC was in effect at the time of the accident. Version D of the AC, titled “Airport Field Condition Assessments and Winter Operations Safety,” was issued on July 29, 2016.

[44] Title 14 *CFR* 139.313, Snow and Ice Control, required airports certificated by the FAA under Part 139 to prepare, maintain, and carry out a snow and ice control plan that described procedures for the prompt removal of snow, ice, and slush on each aircraft movement area. The regulation also required airport operators to promptly notify all air carriers, via NOTAM, when any portion of the movement area was “less than satisfactorily cleared” for safe aircraft operations.

The FAA's airport certification safety inspector (ACSI) for LGA, who began overseeing airport operations there in February 2014, believed that an airport did not need to issue a new NOTAM if the airport were able to "maintain the condition," that is, ensuring that the runway contamination depth does not exceed the depth published in the NOTAM. He also stated that, although it was possible for an airport to keep a NOTAM open for several hours, it would be prudent for the airport to update the NOTAM time and date stamp so that operators would know that the airport was actively monitoring snow conditions on the field.

### 1.5.3 Runway Friction Assessments

LGA had two vehicles with continuous friction measuring equipment (CFME), which use a fifth wheel (either built into an airport vehicle or towed separately by the vehicle) to measure the friction of contaminated pavement surfaces. LGA's chief operations supervisor stated that the CFME vehicles were only used to measure runway friction as it related to assessing the need for rubber removal. He explained that the decision not to use the CFME vehicles for winter operations was related to the FAA's 2008 revisions to AC 150/5200-30C. The AC stated that airports could no longer correlate a Mu value (representing the coefficient of friction between a tire and the runway surface) to runway friction conditions.[45] The AC further stated, "although the FAA no longer recommends providing friction measurements [Mu values] to pilots…some airport users still consider runway friction measurement values to be useful information for tracking the trend of changing runway conditions."

Port Authority thought that the FAA's guidance was unclear regarding whether (1) the FAA was recommending that airport operators conduct runway friction surveys and (2) these surveys were optional or required under certain weather conditions. As a result, on November 20, 2009, the general manager of Port Authority's aviation department asked the FAA's director of Airport Safety and Standards whether airports should conduct runway friction surveys and publish Mu values to interested parties. In a January 13, 2010, letter, the FAA responded, "while we have not been able to correlate runway friction survey data with aircraft performance, we continue to believe operational testing under winter conditions can be a valuable tool to airport operators in providing information on changing runway conditions." The FAA also stated that airport operators were not required to conduct runway friction surveys and that airport operators could provide friction measurement values to interested parties (such as aircraft dispatchers) but not pilots.

On November 22, 2011, the director of Port Authority's aviation department issued a memorandum to the managers of all airports operated by Port Authority.[46] The memorandum,

[45] The AC also stated that earlier FAA research indicated that "measurements using approved friction measuring devices would provide pilots with an objective assessment of the braking action that could be expected on the runway" but that "later research has not been able to identify a consistent and usable correlation between those measurements and airplane braking performance."

[46] Besides LGA, Port Authority operates John F. Kennedy International Airport (JFK), New York, New York; Newark Liberty International Airport (EWR), Newark, New Jersey; Teterboro Airport, Teterboro, New Jersey; Stewart International Airport, New Windsor, New York; and Atlantic City International Airport, Egg Harbor Township, New Jersey.

titled “Winter Operations Friction Testing and Snow and Ice Control Plans,” detailed a new policy (based on the information provided by the FAA) for reporting friction test results. The policy stated that, during snow removal operations, friction testing could be conducted to provide trend data (Mu values) for airport operations staff, but Mu values could not be included in NOTAMs or communicated to the air traffic control (ATC) tower. The policy also stated that runway friction test results could be provided to interested parties upon request. In addition, the memorandum indicated that “runway friction measurement values can be useful information for tracking the trend of changing runway conditions” and that airport operations personnel can use CFME “as they deem necessary to assess runway surface conditions during winter operations.”

AC 150/5200-30C also provided guidance to airport operators regarding when to conduct runway friction assessments on contaminated surfaces. The AC stated that an airport operator should conduct such assessments “immediately following any aircraft incident or accident on the runway, recognizing that responding ARFF [aircraft rescue and firefighting] or other circumstances may restrict an immediate response.” According to LGA’s airport operations manager and aeronautical operations manager, LGA did not perform a runway friction assessment of runway 13 after the accident because the Port Authority friction testing policy did not require the use of CFME.[47]

The FAA’s ACSI for LGA confirmed that the FAA did not require CFME use but stated that he was unaware that the airport was not using CFME during winter operations. He thought that CFME was being used for friction measurements based on statements in LGA’s *Airport Certification Manual* and letter of agreement with the ATC tower. Section 139.313 of the manual stated that “LGA utilizes a CFME type friction tester to conduct friction readings when conditions require trend analysis on a frozen or contaminated surface.” The letter of agreement with the ATC tower, which became effective on October 1, 2012, stated the following:

> When it becomes apparent that conditions may result in degraded runway surface friction, Airport Operations may conduct friction assessments using whatever techniques the Airport Duty Manager or Snow Coordinator deem appropriate, to include tactile feel, vehicle braking and/or use of continuous friction measuring equipment (CFME).

In addition, at the time of the accident, LGA’s computer-based annual training course for winter operations (for airport operations personnel) addressed the use of friction measuring equipment. The training included a video that indicated that the interval between friction tests during winter conditions could vary from “hourly in rapidly changing conditions” to “every 8 hours in more stable conditions” and that “if pilot reports are consistent with favorable braking action the interval can be extended.” The video also indicated that friction testing was also to be conducted when a closed runway was reopened after snow removal operations, with a pilot

[47] Delta’s systems operations manager stated that the company asked LGA airport operations, about 20 minutes after the accident, to conduct a runway friction assessment of runway 13. The systems operations manager stated that the request was denied because “Port Authority Airport Operations personnel no longer conducted runway friction tests” and “did not believe their vehicle…was still calibrated to do so.”

braking action report of nil or two consecutive pilot braking action reports of poor, or after any aircraft accident or incident on the runway.[48] LGA's aeronautical operations manager stated that the video was revised after the accident to indicate the following: "to help determine the best timing for de-ice or anti-ice application or snow removal, instruments that detect pavement conditions and friction measuring equipment can be very helpful."

## 1.6 Flight Recorders

The airplane was equipped with an L-3/Fairchild FA2100-1020 solid-state CVR. The 122-minute 7-second accident recording began at 0900:47, before the airplane departed from ATL, and ended at 1102:54, immediately after the airplane came to rest. A partial transcript was prepared for the portion of the flight between 0954:52 and 0959:00, when the flight crew began discussing the approach to LGA, and a full transcript was prepared for the portion of the flight from 1005:24 to the end of the recording.[49]

The airplane was also equipped with a Lockheed 209F FDR. About 25 hours of operational data were retained on the magnetic tape, including 1 hour 40 minutes of data from the accident flight. The airplane was also equipped with an Avionica mini-quick access recorder (QAR) MKII. QARs are used primarily as a data source for airline flight operational quality assurance (FOQA) programs and can record up to 400 hours of flight data. The QAR installed on the accident airplane recorded about 119 hours of data. The QAR also recorded the same data stream as the FDR. Because of issues with data signal dropouts from the FDR magnetic tape (which contained the recorded airplane data), both FDR and QAR data were used during this investigation.[50]

## 1.7 Survival Aspects

### 1.7.1 Evacuation

The airplane had emergency door exits in the forward cabin (1L and 1R) and the aft cabin (2L), four overwing emergency exits (two by the left wing and two by the right wing), and a tailcone emergency exit. During postaccident interviews and in postaccident statements, the flight attendants provided the following information regarding the evacuation:

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[48] According to AC 25-32, "Landing Performance Data for Time-of-Arrival Landing Performance Assessment," which was issued on December 22, 2015, with poor braking action, "braking deceleration is significantly reduced for the wheel braking effort applied, or directional control is significantly reduced." With nil braking action, "braking deceleration is minimal to non-existent for the wheel braking effort applied, or directional control is uncertain."

[49] Between 0959:00 and 1005:24, the CVR recording included routine ATC transmissions and routine comments between the pilots about the flight.

[50] All parameters, except for those related to engine speed and pressure altitude, became invalid during the accident landing (and before the FDR and QAR lost power) due to damage to the airplane's electronic equipment bay resulting from the airplane's departure from the runway and impact with terrain.

Flight attendant 1 (seated at the main cabin door) reported that, once the airplane stopped, she shouted commands to the passengers to stay seated and calm and then asked whether anyone was injured. One passenger pointed to another passenger in the middle of the cabin, so flight attendant 1 unbuckled her restraint and left her emergency exit to check on that passenger, who was not injured. After the cockpit door opened, flight attendant 1 returned to the front of the cabin, and the captain asked her about the availability of the forward and 2L doors for an evacuation. She had seen water outside the left-side windows in the cabin and advised the captain that the forward doors were not available. She walked back to the 2L door to check its availability and, after returning to the front of the cabin, told the captain that the exit looked "ok" but expressed concern that the slide might not properly deploy because of the snow and debris associated with the accident.

Flight attendant 2 (seated at the 2L door) remained buckled in her jumpseat at first. She tried to use the interphone to reach the flight deck and lead flight attendant but was unable to do so because the airplane had no power. Flight attendant 3 (seated in the aft tailcone jumpseat) was shouting commands to passengers to stay seated and calm. She had not heard a command from the captain to evacuate, so she unbuckled her restraint and began to check on passengers. She and flight attendant 2 then left their emergency exits and walked forward to the front of the cabin, informing passengers to stay in their seats and stay calm. As flight attendants 2 and 3 approached the front of the cabin, they saw the water and the damaged left wing. Flight attendant 3 told the captain that she had assessed the overwing exits as she walked forward and determined that the right-side exits were usable for an evacuation. He asked whether the tailcone exit could be used; she replied that she did not know.

Flight attendant 2 decided to return to the back of the cabin because no one was monitoring that area. As she walked aft, a passenger stopped her and pointed to a first responder who was motioning for the passenger to open a right overwing exit.[51] She told the passenger, "no, we need to wait until our captain instructs us to evacuate."

The captain told flight attendants 1 and 3 that they needed to prepare to evacuate and then handed flight attendant 1 the megaphone from the overhead bin in the forward cabin.[52] As flight attendant 3 returned to the aft cabin, she noticed passengers using their cell phones and began commanding passengers to hang up, get their coats on, and prepare to evacuate.

Flight attendant 1 told passengers, via a megaphone, that they were going to evacuate. She told them to put on their coats and asked passengers wearing high heels to remove them (in

[51] During a postaccident interview, the LGA snow coordinator stated that he had climbed the berm near the nose of the airplane and attempted, but was unable, to get the flight crew's attention (from the side window near the first officer's seat) to open the right overwing exits. He then moved toward the right overwing exits and attempted to get the attention of someone inside the cabin because "there was a sense of urgency to get [the passengers and crew] off" the airplane.

[52] Paragraph (f) of 14 *CFR* 121.309, Emergency Equipment, required each passenger-carrying airplane to have portable battery-powered megaphones readily accessible to crewmembers to direct an emergency evacuation. The megaphones were to be installed at the forward end of the airplane and the most rearward location where the megaphone would be readily accessible from a normal flight attendant seat.

case the wing was slippery). Passengers in the aft cabin reported that they could not hear the flight attendant, even with the megaphone. She moved closer to the overwing exits and told passengers seated near the right overwing exits to open the exits and put the exit hatches on their seats. She then instructed passengers to move quickly to the right overwing exits. The flight attendant asked for assistance from able-bodied passengers to stand outside and help people off the wing.

A firefighter told the captain that passengers should also evacuate through the tailcone exit, so flight attendant 1 directed older passengers and children to the tailcone because she thought that it would be easier for them to exit via the slide there. When flight attendant 3 opened the tailcone, she "saw water" and immediately closed the door, assuming that the exit was unusable. With the megaphone from the overhead bin in the aft cabin, she commanded "bad exit, go forward!" A passenger seated at the 2L emergency exit row told her that the water might have been from a firefighter's hose. She opened the exit again and could "see snow, but no slide."[53] She then commanded passengers to leave their belongings except for their coats and come to the edge of the tailcone, sit down, and jump to the ground, where ARFF personnel were positioned.

Once all of the passengers had evacuated the airplane, the flight attendants and the flight crew evacuated the airplane from the tailcone exit. The passengers were transported to the terminal via shuttle buses. Port Authority personnel asked for the flight and cabin crews' identification and the passenger count. Flight attendant 1 provided the top portion of the flight's departure report, which showed that 125 passengers were aboard the airplane.[54] The pilots and the flight attendants were then transported to the terminal via a shuttle bus.

Later that day, LGA airport operations staff learned that 127 passengers were actually aboard the airplane; 2 lap-held children had not been included in the initial passenger count.[55] In addition, Delta faxed a document, titled "Emergency Passenger Manifest," to the National Transportation Safety Board (NTSB) at 1325, 2 hours 23 minutes after the accident, to provide assistance to families affected by the accident. The manifest listed the names of the

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[53] The slide had inflated under the airplane because of the airplane's attitude.

[54] Delta's preflight procedures required customer service agents to generate a departure report for a flight no more than 15 minutes before the flight's scheduled departure time to ensure that the passenger information was as accurate as possible and then provide this information to the flight attendants. The passenger count included in the report was based on the scanned boarding passes of those passengers aboard the airplane. The passenger count did not include lap-held children; they were noted in the body of the departure report as "INFT" (infant in arms) along with an adult's name and seat location.

[55] The FAA's Air Carrier Operations Bulletin 8-91-2, "Accident Notification and Manifest Accounting Procedures" (dated November 12, 1991), stated that "the word 'passenger,' as used throughout the Federal Aviation Regulations, means any passenger regardless of age." The bulletin was the result of Safety Recommendation A-90-105, which was issued on August 3, 1990, as part of the NTSB's investigation of the 1989 accident involving USAir flight 5050, a Boeing 737, at LGA. Safety Recommendation A-90-105 asked the FAA, in part, to "require airlines to provide airport crash/fire rescue personnel accurate and timely numbers of all persons aboard an accident/incident aircraft." The recommendation was classified "Closed—Acceptable Action" on April 1, 1992. The safety recommendation letter can be found by accessing the Safety Recommendations link on the NTSB's Aviation Information Resources webpage.

127 passengers and 5 crewmembers aboard the airplane and noted that 2 of the passengers were lap-held children.

In addition to the information from the flight attendants' postaccident interviews and statements regarding the evacuation, a passenger, who was seated in the aft cabin behind the left wing, provided the NTSB with cell phone videos from the evacuation.[56] The videos indicated that the passengers were first told about an evacuation about 6 minutes after the airplane came to a stop, and they began exiting the airplane about 6 minutes later (about 12 minutes after the airplane stopped). By the time that all of the passengers had evacuated, more than 17 minutes had elapsed since the time that the airplane came to a stop. The following information appeared on the videos:

- The first video (54 seconds in duration) showed flight attendants 2 and 3 walking toward the front of the cabin. A glimpse of the outside conditions showed the airplane's damaged left wing and the damaged perimeter fence. Passengers were standing in the aisle retrieving and donning coats.
- The second video (1 minute 47 seconds in duration) showed flight attendants 2 and 3 in the mid-cabin moving toward the aft cabin. Flight attendant 2 told passengers toward the aft cabin, "we're going to have to evacuate." Flight attendant 1 stated, over the megaphone, "we are going to start the evacuation process. The only exits you are required to use right now are the window exits. We will have to do this very calmly, slowly, and single file out of the exit. Please do not take any luggage with you. If you have coats, hats, scarves, gloves, that's great; it's cold outside. Please remain seated. No luggage. Please, no luggage." A passenger seated in the aft cabin asked flight attendant 2, "when do we anticipate getting our luggage?" and she replied, "we just need to get off the aircraft."
- The second video also showed some passengers standing in the aisle donning coats and others seated while using cell phones. Flight attendant 3 was moving toward the aft cabin and was closing overhead bins. She said, "calm down. We aren't ready [to evacuate]." Flight attendant 1 said, over the megaphone, "if we crowd in the aisle we can't help, we can't do anything. We are waiting for instruction. We have fire crews outside the aircraft that will help you off the plane." Flight attendant 3 asked, "are we doing this now?" and flight attendant 1 replied, "I don't know." Flight attendant 2 then stated, "we need everyone to stay seated unless you are getting your coats." Flight attendant 3 continued to close overhead bins and said, "stay seated until we direct you otherwise" and "everyone stay seated, no bags, no bags, no luggage." Flight attendant 3 continued to move toward the aft cabin and said to passengers in the aisle, "you all need to move, I need to get back here to my exit."

[56] The passenger also provided cell phone photographs. The photographs showed (in the order that they were taken) the left wing over Flushing Bay, over the runway near the 500-foot marker, and inside the damaged perimeter fence; the tailcone slide; and passengers on the tarmac in snow conditions with a fire truck positioned behind the airplane and two firefighters on the wing helping passengers out of the airplane.

- The third video (1 minute 37 seconds in duration) showed passengers in the aisle with coats and gloves. A passenger asked, "are we going that way or this way?" Another passenger responded, "this way is fine, come this way." Passengers moved toward the tailcone exit. Flight attendant 3 commanded, "sit on your butt, stay low, stay calm." Passengers continued to move through the tailcone. Flight attendant 3 thanked a passenger for helping with the evacuation and then instructed him to evacuate.
- The portion of the third video that was taken from outside of the airplane showed snow on the ground and fire trucks, police cars, and first responders near the airplane. Flight attendant 3 was positioned at the tailcone exit with two firefighters outside the tailcone helping passengers deplane. Passengers were also shown exiting the airplane using the right overwing exits. A first responder announced, "this way please, sir, over here, you need to go over there. Excuse me guys over there." Passengers were shown using cell phones and carrying handbags and backpacks.

### 1.7.2 Emergency Response

After the airplane departed the runway and came to a stop, the leader of the red snow removal team (in a vehicle on a taxiway near the departure end of runway 13) saw that the airplane had hit a fence and notified the LGA snow coordinator. The snow coordinator (with the blue team in a snow removal vehicle with the call sign "car 100") was unable to see the airplane from the vehicle's location at the time, but he had been monitoring the ATC tower frequency and knew that ATC had lost communication with the airplane. Table 5 shows the accident notification events that followed, as indicated from ATC recordings and ASDE-X video data.

**Table 5.** Accident notification events.

| Time | Event |
|---|---|
| 1103:45 to 1104:00 | Car 100 requested permission from the local controller to cross runway 4; permission was granted. Car 100 entered runway 4, turned northbound, and notified the controller that runway 13 was closed; no response was received. |
| 1104:08 | Red team requested permission to proceed onto runway 13. |
| 1104:10 | Car 100 entered the intersection of runway 4 and runway 13. |
| 1104:12 to 1104:19 | Car 100 told the controller again that runway 13 was closed, the controller questioned if he heard the information correctly, and car 100 confirmed that the runway was closed. |
| 1104:24 | Red team told the controller, "you have an aircraft off the runway." |
| 1104:35 | ARFF personnel received the first indication of the accident. Airport operations personnel notified, via telephone, the airport operations manager that an airplane had departed the paved runway surface and had a fuel leak. The airport operations manager had been meeting at the time with the ARFF deputy chief, who then contacted the ARFF crew chief, via telephone, to prepare ARFF personnel and vehicles to launch to the scene. |
| 1104:38 to 1104:44 | Car 100 told the controller that the "airport is closed!" and that "we've got a 3-4!"[a] The controller asked that the information be repeated. |
| 1104:48 | An LGA operations staff member told the controller that "you have an aircraft off [runway] 3-1 on the north vehicle service road. Please advise crash/rescue. LaGuardia Airport is closed at this time." |
| 1105:11 | Car 100 arrived near the accident site. |
| 1105:55 to 1106:05 | An unknown speaker told the controller that the airplane was "leaking fuel on the left side of his aircraft heavily" and that "his wing is ruptured." |
| 1106:25 | The ATC tower activated LGA's emergency alert notification system (EANS), stating, "LaGuardia, Alert 3, all emergency vehicles respond. Alert 3, Delta 1086 MD-80, just east of runway 1-3, wing eruption, fuel is being leaked." |

[a] The term "3-4" had previously been used by Port Authority to describe the highest alert level for an airplane emergency at LGA. The Port Authority/LGA ATC tower letter of agreement, dated March 31, 2014, stated that an airplane accident was to be referred to as an "alert 3."

At 1104:33, while the events in table 5 were occurring, the local controller was instructing the flight crew of Delta flight 1999, which had checked in with the controller 2 minutes earlier, to go around, climb, and maintain an altitude of 2,000 feet. At 1105:04, the flight 1999 airplane crossed over the runway 13 threshold while climbing through an altitude of 1,800 feet.

The EANS was the primary method for communicating an emergency at LGA. The EANS, after activation by the ATC tower, provided audible tones over a loud speaker in the ARFF station, airport operations office, and the Port Authority Police Department along with a verbal description of the emergency and its location.

Because the airplane's location was not provided as part of the initial notification to the airport operations manager, ARFF units initially responded to the fenced area at the approach end of runway 13. Radio communications indicated that ARFF crews were still unclear about the severity and location of the accident as of 1110:12. After firefighters saw the airplane on the embankment next to Flushing Bay, they arrived at the accident site at 1111:02, which was more than 8 minutes after the accident occurred.

The on-airport ARFF response included the ARFF deputy chief, 14 ARFF personnel, four firefighting vehicles, and one airstair truck. Three ARFF vehicles were positioned at the tail of the airplane, and turrets on two of the vehicles were used to apply aqueous film-forming foam to the left wing area, from where fuel was leaking. The evacuation began about 4 minutes after ARFF arrived on scene, and ARFF personnel assisted passengers off of the right wing and out of the tailcone.

## 1.8 Tests and Research: Aircraft Performance Study

The NTSB conducted an aircraft performance study for this accident to determine the airplane's position and orientation during final approach and the landing roll and the airplane's response to control inputs, wind, and ground forces, which could affect the airplane's trajectory. According to the study, the airplane was on the appropriate glideslope and heading while on approach into LGA. The airplane's speed at touchdown, 133 knots, was consistent with a $V_{ref}$ of 131 knots (+5 knots to correct for the wind). The airplane's main gear touched down 600 feet from the runway 13 threshold, and the nose gear touched down 1,200 feet from the threshold. The braking devices (spoilers, thrust reversers, and autobrakes) were fully deployed between the time that the main gear and the nose gear touched down. The airplane began to yaw to the left about 1,500 feet from the runway threshold. The flight crew made right rudder inputs in response to the left yaw, but the airplane veered to a heading of 114º (20º left of the runway 13 heading of 134º) before the airplane departed the left side of the runway about 3,200 feet from the runway threshold.

As part of the aircraft performance study, the NTSB considered the events surrounding the airplane's loss of directional control, compared data from the accident landing with that of the preceding airplane, and examined the EPR levels in reverse thrust for other recorded landings from two Delta MD-88 airplanes. The sections that follow discuss this information.

### 1.8.1 Loss of Directional Control

According to the FDR, the EPR values began to increase rapidly after the thrust reversers were deployed at 1102:17.5 (as discussed further below). The left yaw rate began at 1102:20.5, when the airplane was about 1,500 feet from the runway threshold, and the flight crew responded by applying right rudder at that time. The left yaw rate increased to about 2.5º/sec at 1102:22.5 and remained at that rate for the next 1.5 seconds. At 1102:24, the crew released the rudder pedal, and the rudder deflection decreased. The left yaw rate began to increase again as the rudder pedal was released. The flight crew made a second right rudder pedal input about the same time as the thrust reversers were stowed and right manual braking began (1102:25), and the increase in the left yaw rate was arrested and then began to decrease 1 second later. After the second right rudder pedal input, the rudder reached its maximum deflection of 23º by 1102:26.5.

While the thrust reversers were deployed, the EPR values exceeded 1.6 for about 5 seconds. The left engine exceeded 1.6 EPR at 1102:20.3, reaching a maximum of 2.07 EPR. The right engine exceeded 1.6 EPR at 1102:21.0, reaching a maximum of 1.91 EPR. The airplane's airspeed was under 130 knots when the EPR values were above 1.6. As discussed in section 1.3.1, Boeing's flight test data showed that, with reverse thrust above 1.6 EPR and an airspeed under 146 knots, the rudder had limited directional authority (McDonnell Douglas Corporation, 1980). Thus, during the 4.5 seconds from the time that the airplane's left yaw began (1102:20.5) to the time that the thrust reversers were stowed (1102:25), the rudder was blanked by the thrust reversers, causing the rudder to be ineffective in controlling the airplane's heading. Once the thrust reversers were stowed and rudder authority was restored, the left yaw rate could be reduced.

Nosewheel steering (available through the rudder pedals once the nose gear strut compressed) was calculated to have increased to 3.5º right during the initial input in right rudder pedal (1102:20.5) and to more than 11º right during the second application of right rudder pedal (1102:25). Between 1102:22.5 and 1102:24, when the left yaw rate remained steady at a rate of about 2.5º/sec, the rudder was rendered ineffective due to high EPR values, so the pause in the left yaw acceleration might have been the result of nosewheel steering inputs. However, these inputs were not sufficient to redirect the airplane until they were used along with rudder inputs and differential braking after the thrust reversers were stowed.

Right differential braking was applied at 1102:25 as the second right rudder input was made. Right braking pressure increased to just below 400 psi at 1102:27, decreased to 0 psi 1 second later, and then increased to more than 1,100 psi at 1102:29. The left yaw rate dropped with the onset of differential braking, but the airplane departed the runway about 1102:30. Thus, right differential braking contributed to controlling the airplane's heading but not until after the thrust reversers were stowed.

The possible forces that might have contributed to the initial left heading deviation include a yawing moment resulting from asymmetric reverse thrust (given that the right engine EPR lagged behind the left engine EPR), a sudden increased crosswind, and the landing roll braking action (which is discussed further in the next section). The data that were available showed that no single event or environmental factor seemed likely on its own to be able to impart the yawing moment that the airplane experienced. Thus, according to the study, a combination of these factors likely caused the airplane's initial deviation from the runway heading.

### 1.8.2 Comparison of Preceding Flight and Accident Flight

The NTSB reviewed FDR data from the preceding flight, a Delta MD-88 airplane that landed on runway 13 without incident about 2.5 minutes before the accident landing, to compare both airplanes' stopping performance. Table 6 compares pertinent data from both landings.

**Table 6.** Landing data comparison.

| Event | Preceding airplane | Accident airplane |
|---|---|---|
| Landing weight | 112,500 pounds | 127,500 pounds |
| Flap configuration | 40º | 40º |
| $V_{ref}$ | 124 knots | 131 knots |
| Main gear touchdown time | 1059:55 | 1102:16 |
| Main gear touchdown speed | 125 knots | 133 knots |
| Main gear touchdown location | 700 feet from runway threshold | 600 feet from runway threshold |
| Nose gear touchdown location | 1,100 feet from runway threshold | 1,200 feet from runway threshold |
| Spoiler deployment | About 1 second after main gear touchdown | About 1 second after main gear touchdown |
| Thrust reverser deployment | About 1.5 seconds after main gear touchdown | About 1 second after main gear touchdown |
| Autobrake initiation (maximum autobrakes) | About 1 second after main gear touchdown | About 2 seconds after main gear touchdown |
| Maximum EPR values | 1.82 left and 1.53 right | 2.07 left and 1.91 right |
| Maximum rudder input | 10º to the left | 23º to the right |

The comparison of landing data also showed that, for the first 2,500 feet on runway 13, both airplanes followed similar groundpaths, with both airplanes' ground tracks within 10 feet of each other until the accident airplane's heading began to drift to the left. (The preceding airplane did not deviate from the runway heading throughout the landing roll.) Both airplanes' braking devices deployed along similar timeframes, but the preceding airplane's maximum EPR values (1.82 and 1.53) did not increase to the same levels as those for the accident airplane (2.07 and 1.91).

In addition, the NTSB and Boeing performed simulations for both the accident airplane and the preceding airplane using Boeing MD-88 aerodynamic, engine, and ground interaction models. Recorded engine and flight control data from the accident airplane's FDR and the preceding airplane's FDR were included in the simulations. For each simulation run, a constant airplane wheel/runway interface performance value was used. Specifically, a wet runway condition had a wheel braking coefficient of 0.31, an icy runway condition had a wheel braking coefficient of 0.07, and an intermediate runway condition had a wheel braking coefficient of 0.16.[57] The wet and icy wheel braking coefficients were Boeing reference values. The

[57] According to AC 25-32, "wheel braking coefficient is the ratio of the deceleration force from a braked wheel/tire relative to the normal force acting on the wheel/tire. The wheel braking coefficient is an all-inclusive term that incorporates effects related to the tire-to-ground interaction from braked wheels only, such as runway surface and airplane braking system (e.g., anti-skid efficiency, brake wear, tire condition, etc.)."

intermediate value was based on landing performance information in AC 25-32. The simulations showed that the wheel braking coefficients for the accident airplane and the preceding airplane were both about 0.16 or better, which would be considered, at a minimum, medium braking action according to AC 25-32.[58]

### 1.8.3 Engine Pressure Ratio Levels During Other Landings

The NTSB reviewed landing data from two different Delta MD-88 airplanes to determine how often EPR reverse thrust guidance levels (1.3 EPR for contaminated runways and 1.6 EPR for dry runways) were exceeded during landing. A total of 80 landings were analyzed for trends in the magnitude of reverse thrust EPR, the magnitude of rudder applied, variations in heading during the landing roll, and the weather.[59]

Of the 80 landings, 14 occurred with precipitation (as determined from archived meteorological aerodrome reports), including two landings with snow. Although the amount and type of runway contamination could not be determined from the available information, the 14 landings with precipitation all had maximum reverse thrust EPR values above 1.3, and 8 of the 14 landings had maximum reverse thrust EPR values above 1.6.

Also, 35 of the 80 landings occurred with at least one engine above 1.6 EPR. The average time between the left engine reaching 1.3 and 1.6 EPR was about 1.25 seconds. The time between those values for the accident flight was 0.5 second. The EPR values during the accident flight (2.07 on the left engine and 1.91 on the right engine) were higher than all EPR values in the landing data reviewed.

In addition, 37 of the 80 landings occurred with crosswinds above 5 knots. Nine of the 37 landings occurred with crosswinds above 10 knots, and 16 of the 37 landings involved an EPR of 1.6 or above. Also, 62 of the 80 landings involved more maximum rudder inputs to the right than to the left, even though there were about the same number of landings with a left crosswind as a right crosswind. The rudder input direction was more strongly associated with asymmetric EPR levels between engines than the crosswind direction.

The landing data were also reviewed to determine whether any factors might influence a pilot to input a high reverse thrust EPR. The data showed that the airspeed at touchdown and the available runway length were minimally correlated with the maximum EPR values.[60] In addition, the ambient air temperature and the presence of precipitation showed no correlation with the maximum EPR values.

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[58] AC 25-32 defined “medium” braking action as follows: “braking deceleration is noticeably reduced for the wheel braking effort applied, or directional control is noticeably reduced.” This definition was consistent with the definition in Delta’s *Operational Data Manual* for medium braking action.

[59] These landings occurred at airports throughout the United States.

[60] The mean touchdown speed was 123 knots. The available runway length was determined for 34 of the 80 landings.

## 1.9 Organizational and Management Information

Delta Air Lines is headquartered in Atlanta, Georgia. According to Delta, as of March 2015, the company operated 722 airplanes, including 117 MD-88 and 65 MD-90 airplanes. At that time, the company had 11,709 active pilots, of which 1,014 were MD-88/90 captains and 1,036 were MD-88/90 first officers.

### 1.9.1 Flight Crew Manuals and Guidance

#### 1.9.1.1 Reverse Thrust Operation

The Delta MD-88/90 *Flight Crew Training Manual*, page 6.22, dated January 16, 2014, stated the following under "Reverse Thrust Operation":

> After main gear touchdown and once nose lowering has commenced thrust reversers should be deployed to reverse idle detent. Upon nosewheel touchdown and when the ENG REVERSE UNLOCK and ENG REVERSE THRUST lights illuminate increase reverse thrust as required. The PM should monitor engine operating limits and call out any engine operational limits being approached or exceeded, any thrust reverser failure, or any other abnormalities.[61] Maintain reverse thrust as required, up to maximum, until 80 knots.

Page 6.25 of the manual, under the heading "Reverse Thrust and Crosswind (All Engines), stated the following actions to take if the airplane starts to weathervane (turn) into the wind:

> To correct back to the centerline, release the brakes and reduce reverse thrust to reverse idle. Releasing the brakes increases the tire-cornering capability and contributes to maintaining or regaining directional control. Setting reverse idle reduces the reverse thrust side force component without the requirement to go through a full reverser actuation cycle. Use rudder pedal steering and differential braking as required to prevent over correcting past the runway centerline. When directional control is regained and the aircraft is correcting toward the runway centerline, apply maximum braking and symmetrical reverse thrust to stop the aircraft.
>
> Note: Use of this technique increases the required landing distance.

Two Delta MD-88/90 fleet bulletins referred to 1.3 EPR as a target, rather than as a maximum, on runways that are not dry. Specifically, a bulletin published in November 2014 reminded MD-88 pilots that "for a dry runway the MINIMUM is 1.3 EPR and the TARGET is

[61] The Delta MD-88/90 fleet manager stated that there was no specific callout for EPR target exceedances but that the PM was expected to clearly announce what the EPR gauges displayed.

1.6. On a runway that is not dry, 1.3 EPR is the target." This bulletin also stated that "line check data shows that many pilots accept reverser settings far below the target." Further, a February 2015 bulletin provided the same reminders about EPR targets and stated the following:

> Line check data indicates that many of us can tighten up our reverser operations. Remember that Volume 1 NP.20.76 tells us, 'After main gear touchdown and once nose lowering has commenced thrust reversers may be deployed to reverse idle detent. Upon nosewheel touchdown, normal reverse should be used.' So, wait until the nosewheel gets to the runway to go past idle reverse.

### 1.9.1.2 Landing on Wet or Contaminated Runways

Page 6.15 of the Delta MD-88/90 *Flight Crew Training Manual* stated the following under the heading "Slippery Runway Landing Performance":

> When landing on slippery runways contaminated with ice, snow, slush, or standing water, the reported braking action must be considered. Stopping distances for the various autobrake settings and for non-normal configurations are provided in the ODM [*Operational Data Manual*]. Pilots should use extreme caution to ensure adequate runway length is available when poor braking action is reported.

The information in this section noted that pilots should "consider delaying thrust reverser deployment until nose wheel touchdown, so that directional control is not affected by asymmetric deployment," as well as the following:

> Slippery/contaminated runway performance data is based on an assumption of uniform conditions over the entire runway. This means a uniform depth for slush/standing water for a contaminated runway or a fixed braking coefficient for a slippery runway. The data cannot cover all possible slippery/contaminated runway combinations and does not consider factors such as rubber deposits or heavily painted surfaces near the end of most runways.[62]

Page 6.15 of the manual included the following caution under the heading "Landing on Wet or Slippery Runways":

> Reverse thrust above 1.3 EPR may blank the rudder and degrade directional control effectiveness. However, as long as the aircraft is aligned with runway track, reverse thrust may be used (up to a maximum) to stop the aircraft. Do not attempt to maintain directional control by using asymmetric reverse thrust.

[62] Delta's MD-88/90 *Operations Manual*, volume 1, "Supplementary Procedures – Adverse Weather," dated October 23, 2014, further stated that, when landing on a contaminated runway, "do not assume the last 2,000 feet of the runway will have braking action as good as the touchdown zone."

The information in this section also stated, on page 6.16, that pilots should apply reverse thrust to the idle detent and, after reverse thrust symmetry is verified, gradually increase reverse thrust as required. In addition, pages 6.16 and 6.17 of the manual stated the following:

> If a skid develops, especially in crosswind conditions, reverse thrust will increase the sideward movement of the airplane. In this case, release brake pressure and reduce reverse thrust to reverse idle, and if necessary, to forward idle. Apply rudder as necessary to realign the airplane with the runway and reapply braking and reversing to complete the landing roll.

#### 1.9.1.3 Crosswind and Tailwind Guidance

Delta's MD-88/90 *Operations Manual* stated that the "crosswind limit is 30 knots for takeoff or landing, including gusts" and that "the crosswind component may be further limited by low visibility approaches, contamination, or runway width." Delta's guidelines for contaminated runways were found in the manual's supplementary procedures for adverse weather. The guidelines indicated that, with a braking action of medium/fair, the crosswind component was 20 knots; with a braking action of medium/poor, the crosswind component was 10 knots.

Delta's MD-88/90 *Operations Manual* also stated that the maximum landing tailwind component was 10 knots. The manual's supplementary procedures for adverse weather did not specify procedures for landing with a tailwind on a dry or contaminated runway.

#### 1.9.1.4 Evacuation Procedures

Delta's MD-88 *Operations Manual*, chapter 10, "Emergency Operations," indicated that the flight crew should take the following actions if an evacuation were required:

- Make a pre-evacuation announcement to instruct the cabin crew to prepare for an evacuation.
- Either make the evacuation announcement or state the following to cancel the evacuation: "This is the captain. Remain seated with your seat belt fastened."
- For an evacuation, when directed by the emergency evacuation checklist, state "This is the captain. Evacuate, evacuate." If conditions make certain exits unusable, state the direction of egress.

Delta's MD-88/90 *Flight Crew Training Manual*, chapter 8, "Non-Normal Operations," dated October 23, 2014, stated that, for unplanned evacuations, "the captain needs to analyze the situation carefully before initiating an evacuation order" and that "quick actions in a calm and methodical manner improve the chances of a successful evacuation." The manual also stated that the captain should use "all available sources of information," including reports from the cabin crew, "to determine the safest course of action." The manual further stated that "the captain must then determine the best means of evacuation by carefully considering all factors," which included, but were not limited to, the urgency of the situation, the type of threat to the airplane, and the extent of damage to the aircraft. In addition, the manual recognized that there could be a need to deplane passengers under circumstances that are not urgent.

### 1.9.2 Flight Crew Training

Delta's MD-88/90 recurrent training during the 3 years before the accident included instruction on contaminated runway operations and the use of reverse thrust. During the recurrent training cycle from July 2012 to March 2013, special purpose operations training incorporated a simulator scenario that required pilots to land with a 10-knot crosswind in heavy rain on an ungrooved contaminated runway.[63] This training module included the following guidance to pilots:

> Additional reverse thrust should be applied while watching carefully for signs of directional control problems. Remember, applying reverse thrust above 1.3 EPR will potentially blank rudder effectiveness and degrade directional control.
>
> If directional control is compromised, reduce reverse thrust to idle reverse and hold forward stick pressure to regain centerline track.

During the recurrent training cycle from April to December 2013, special purpose operations training addressed takeoffs on contaminated runways. One simulator scenario used the same contaminated runway conditions included in the previous training cycle. During the recurrent training cycle from January to September 2014, training addressed properly calculating landing distances using charts from the *Operational Data Manual*. The accident pilots' training records indicated that they participated in each of these three training modules.

Delta's MD-88/90 fleet captain oversaw simulator training, the training curriculum, and manual revisions for the operator's MD-88/90 fleet.[64] During a postaccident interview, the fleet captain stated that recent revisions to the MD-88/90 *Flight Crew Training Manual* emphasized the need for MD-88 pilots to target 1.6 EPR on a dry runway and 1.3 EPR on a contaminated runway. He also stated that pilots were trained to wait until the airplane's nose was trending downward and to move the reverse thrust levers symmetrically while watching N1 rpm in case the throttles split. The fleet captain further stated that, in a rudder blanking situation, the key was to neutralize the thrust reversers to idle and regain directional control.

[63] This scenario was based on an event involving a Delta MD-88 at Cancun International Airport (CUN), Cancun, Mexico, on January 14, 2012. During landing, the airplane departed the right side of the runway, but the pilots were able to maneuver the airplane back onto the runway. The runway visibility was 1/2 mile, and the flight crew of the preceding airplane that landed on the runway reported that braking action was medium/fair.

[64] The MD-88/90 fleet captain reported to Delta's managing director of flight training, who reported to Delta's senior vice president for flight operations. The fleet captain also oversaw the Boeing 717 airplane, which is part of the DC-9 series of airplanes.

In addition, Delta's MD-88/90 fleet captain stated that the company provided crosswind training for its pilots but did not provide tailwind simulator training.[65] Company pilots were aware of the 10-knot tailwind component limit from procedural guidance.

### 1.9.3 Flight Attendant Manual

Delta's *In-Flight Service Onboard Manual*, chapter 3, dated March 1, 2015, contained flight attendant evacuation procedures for planned and unanticipated emergencies. The manual stated that unanticipated emergencies usually occurred during taxi, takeoff, and landing with little warning.

The flight attendants were to immediately begin an evacuation when the captain commanded, "This is the captain. Evacuate! Evacuate!" As part of this command, the captain could indicate which exits were to be used in the evacuation. The flight attendants were not supposed to evacuate the airplane if the captain announced, "This is the captain, remain seated with your seat belt fastened." In this situation, the flight attendants were to command, "Stay seated! Sit down! Stay calm!" and await instructions.

The manual stated that flight attendants could begin an evacuation without an order from the captain if conditions were life-threatening ("no doubt, get out"). The manual noted that flight attendants should not initiate an evacuation "if there is no immediate danger after 30 seconds." In this situation, the lead flight attendant was to contact the flight crew for instructions and then advise the other flight attendants.

According to the manual, once an evacuation order or decision was made, the flight attendants were to assess the safety of their assigned exits. If an exit could safely be opened, the flight attendants were to open the exit, command "Come this way! Leave everything!", and evacuate passengers in their respective areas. If an exit could not be safely opened or was inoperable, the flight attendants were to redirect passengers to alternate exits using the commands "bad exit" and "go across," "go forward," or "go back" as appropriate.

The manual did not address procedures for communicating during an emergency or an evacuation when the public address system and/or the interphone were inoperative. Chapter 7 of the manual provided information about crew communication within the airplane during normal operations. For example, the manual stated that, if the public address system were inoperable during normal operations, the lead flight attendant was required to contact the captain to

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[65] On December 7, 2011, the NTSB issued Safety Recommendations A-11-92 through -94 to the FAA to address the need for pilot training for, and guidance about, tailwind landings to mitigate the risk of a runway overrun while landing in tailwind conditions. (The NTSB's safety recommendation letter can be found by accessing the Safety Recommendations link on the NTSB's Aviation Information Resources webpage. The NTSB issued these recommendations as a result of the December 22, 2009, accident involving American Airlines flight 331, a Boeing 737 that departed the end of runway 12 at Norman Manley International Airport, Kingston, Jamaica. The Jamaica Civil Aviation Authority conducted the investigation of this accident and issued the final report in May 2014 (JCAA 2014). On April 6, 2015, the NTSB classified Safety Recommendations A-11-92 and -94 "Open—Acceptable Response" and Safety Recommendation A-11-93 "Closed—Acceptable Action."

establish alternate methods of communication with the passengers, including individual briefings, small group briefings, and communicating with megaphones. Also, the manual stated that, if the interphone were inoperable during normal operations, the lead flight attendant should establish alternate methods of communication with the flight crew and the flight attendants.

### 1.9.4 Flight Attendant Training

Delta provided 68 hours of instructor-led emergency management and event management evaluation training during initial flight attendant training and 19.5 hours of this training during recurrent flight attendant training. During these training modules, situational awareness, safety, crew communication and coordination, workload management, planning and decision-making, and threat and error management skills were evaluated.

During the training, flight attendants participated in evacuation proficiency drills in cabin trainers using taped crash sounds and pilot commands. For example, after a simulated crash, if a flight attendant heard the command, “This is the captain. Evacuate! Evacuate!”, the flight attendant would begin using the required commands and would either open an exit (if it were usable) and begin the evacuation or block the exit (if it were not usable) and redirect passengers. No training scenarios involved a loss of communications. In addition, Delta did not conduct joint flight crew/cabin crew evacuation exercises.

## 1.10 Additional Information

### 1.10.1 Runway Excursion Events

As a result of this accident, the NTSB reviewed its accident and incident data, along with such data from Delta and the National Aeronautics and Space Administration’s Aviation Safety Reporting System, to identify MD-80 series airplane events in which directional control was lost during the landing roll. The NTSB found that, during the 20-year period from January 1995 to January 2015, 14 events involved MD-80s that drifted or veered off the runway during the landing roll. Of these 14 events, 11 resulted in runway excursions (a departure from the side or the end of a runway at any time during landing). Table 7 shows that, of the 11 runway excursions, 8 involved reverse thrust above 1.3 EPR while landing on a contaminated runway, and 5 of these 8 excursions involved reverse thrust at or above 1.6 EPR.

**Table 7.** Landing roll events from January 1995 to January 2015 involving MD-80 series airplanes.

| Date and location | Directional control risk factor | | | | Runway excursion |
|---|---|---|---|---|---|
| | Crosswind | Low visibility | Runway contamination | EPR above 1.3 | |
| January 1995 DCA | | ✓ | ✓ | ✓ (1.62) | ✓ |
| October 1997 ANC | ✓ | ✓ | ✓ | | ✓ |
| March 1997 CLE | ✓ | ✓ | ✓ | ✓ (1.50) | ✓ (Accident) |

| Date and location | Directional control risk factor | | | | Runway excursion |
|---|---|---|---|---|---|
| | Crosswind | Low visibility | Runway contamination | EPR above 1.3 | |
| December 1997 SWF | ✓ | ✓ | ✓ | | ✓ |
| March 1998 CLE | ✓ | ✓ | ✓ | ✓ (1.40) | ✓ |
| March 1998 PVM | ✓ | ✓ | ✓ | | ✓ |
| June 1999 LIT | ✓ | ✓ | ✓ | ✓ (1.89) | ✓ (Accident) |
| August 1999 YUL | ✓ | | ✓ | ✓ (1.80) | |
| August 1999 YUL | ✓ | | ✓ | ✓ (1.60) | |
| February 2000 PSP | ✓ | | | | ✓ |
| September 2002 Unavailable | | | ✓ | | ✓ |
| March 2011 STL | ✓ | ✓ | ✓ | ✓ (1.45) | ✓ |
| January 2012 CUN | | ✓ | ✓ | ✓ (2.00) | ✓ |
| April 2014 MSP | ✓ | ✓ | ✓ | | |
| **Total** | 11 | 10 | 13 | 8 | 11 |

**Note:** DCA, Ronald Reagan Washington National Airport, Washington, DC; ANC, Ted Stevens Anchorage International Airport, Anchorage, Alaska; CLE, Cleveland Hopkins International Airport, Cleveland, Ohio; SWF, Stewart International Airport, New Windsor, New York; PVM, Portland International Jetport, Portland, Maine; LIT, Clinton International Airport, Little Rock, Arkansas; YUL, Montreal-Pierre Elliot Trudeau International Airport, Quebec, Canada; PSP, Palm Springs International Airport, Palm Springs, California; STL, Lambert-St. Louis International Airport, St. Louis, Missouri; MSP, Minneapoilis-St.Paul International Airport, Minneapolis, Minnesota.

As shown in the table, four of the events (March 1997, March 1998, June 1999, and March 2011) included each directional control risk factor. These four events all resulted in runway excursions, and two of those four events (March 1997 and June 1999) resulted in accidents. In addition, all four risk factors were present in the accident involving Delta flight 1086.

### 1.10.2 Takeoff and Landing Performance Assessment Aviation Rulemaking Committee

The FAA formed the Takeoff and Landing Performance Assessment (TALPA) Aviation Rulemaking Committee (ARC) after the December 8, 2005, accident involving Southwest Airlines flight 1248, a Boeing 737 that overran the runway after landing at Chicago Midway International Airport, Chicago, Illinois. After the overrun, the airplane rolled through a blast fence and an airport perimeter fence and onto an adjacent roadway, where it struck an automobile before coming to a stop (NTSB 2007).[66]

[66] Section 1.10.3.2 discusses two of the NTSB's recommendations resulting from this accident.

According to the FAA, the purpose of the TALPA ARC was to develop recommendations for improving the safety of operations on contaminated runways during takeoffs and landings. Members of the TALPA ARC included air carriers/operators, aircraft manufacturers. airport operators, dispatchers, pilot union representatives, and industry regulators. Among the recommendations resulting from this effort were the use of the runway condition assessment matrix (RCAM), as described below, and the use of common terminology for determining and reporting runway surface conditions.

Starting October 1, 2016, airport operators will be required to use the RCAM, as shown in figure 5, to report runway surface conditions and publish the results through NOTAMs. The RCAM will use “0” through “6” to describe the conditions along each one-third of the runway (the touchdown, midpoint, and rollout segments), which will determine the runway condition code—for example, 3/3/3 for a runway contaminated with wet or dry snow with a depth of more than 1/8 inch, consistent with a pilot report of medium braking action. Aircraft operators would then use that information as part of flight planning and decision-making.

Besides the RCAM tool for airports, there are optional RCAM tools for aircraft operators and for airframe manufacturers and other providers of landing performance data. On June 9, 2016, the FAA held an industry-wide rollout for the TALPA program, with several NTSB staff members in attendance. During one of the presentations, the FAA stated that the operational RCAM was designed to be a decision-support tool rather than a decision-making tool. Among other things, the operational RCAM considers the method in which an airport conducts a runway condition assessment as well as a pilot’s experience with braking action.

In addition, as part of the TALPA program, the FAA issued two ACs on December 22, 2015. AC 25-31 provided guidance and standardized methods for developing takeoff performance data for Part 121 airplanes for operations on contaminated runways. AC 25-32 (discussed in sections 1.5.3 and 1.8.2) provided guidance and standardized methods for developing data for time-of-arrival (or en route) landing performance assessments for Part 121 airplanes. Both ACs promoted the use of consistent terminology for runway surface conditions among data providers and FAA personnel. On August 15, 2016, the FAA issued Safety Alert for Operators (SAFO) 16009, “Runway Assessment and Condition Reporting,” to notify operators, pilots, and other personnel of the changes in runway condition reporting, starting October 1, 2016, for runways that are not dry.

| **Runway Condition Assessment Matrix (RCAM)** | | | | |
|---|---|---|---|---|
| **Assessment Criteria** | | **Downgrade Assessment Criteria** | | |
| **Runway Condition Description** | **Code** | **Mu (μ)** | **Vehicle Deceleration Or Directional Control Observation** | **Pilot Reported Braking Action** |
| • Dry | 6 | 40 or Higher | --- | --- |
| • Frost<br>• Wet (Includes Damp and1/8" depth or less of Water)<br>***1/8" (3 mm) depth or less of:***<br>• Slush<br>• Dry Snow<br>• Wet Snow | 5 | 40 or Higher | Braking deceleration is normal for the wheel braking effort applied AND directional control is normal. | Good |
| ***5° F (-15°C) and Colder outside air temperature:***<br>• Compacted Snow | 4 | 39 to 30 | Braking deceleration OR directional control is between Good and Medium. | Good to Medium |
| •Slippery When Wet (wet runway)<br>• Dry Snow or Wet Snow (Any depth) over Compacted Snow<br>***Greater than 1/8" (3 mm) depth of:***<br>• Dry Snow<br>• Wet Snow<br>***Warmer than 5° F (-15°C) outside air temperature:***<br>• Compacted Snow | 3 | 39 to 30 | Braking deceleration is noticeably reduced for the wheel braking effort applied OR directional control is noticeably reduced. | Medium |
| ***Greater than 1/8" (3 mm) depth of:***<br>• Water<br>• Slush | 2 | 29 to 21 | Braking deceleration OR directional control is between Medium and Poor. | Medium to Poor |
| • Ice | 1 | 29 to 21 | Braking deceleration is significantly reduced for the wheel braking effort applied OR directional control is significantly reduced. | Poor |
| • Wet Ice<br>• Slush over Ice<br>• Water on top of Compacted Snow<br>• Dry Snow or Wet Snow over Ice | 0 | 20 or Lower | Braking deceleration is minimal to non-existent for the wheel braking effort applied OR directional control is uncertain. | Nil |

**Source:** FAA.

**Figure 5**. Runway condition assessment matrix to be used by airport operators (as of June 2016).

### 1.10.3 Previous Safety Recommendations

#### 1.10.3.1 Reverse Thrust Power

On December 10, 2001, the NTSB issued Safety Recommendations A-01-51 through -53 as a result of our investigation of the June 1, 1999, American Airlines flight 1420 accident in

Little Rock, Arkansas. The airplane, an MD-82, began sliding on the runway after landing, and the airplane's drift angle while on the runway reached as much as 16º both to the right and to the left of the direction of travel. Although the NTSB found that the flight crew had not ensured that the spoilers extended after touchdown, the NTSB also found that the flight crew applied excessive reverse thrust several times before the airplane departed the runway. Both American's and Boeing's operating manuals indicated that pilots were not to exceed 1.3 EPR on contaminated runways except in an emergency. The flight 1420 crew applied reverse thrust as high as 1.98 EPR on the left engine and 1.74 EPR on the right engine. The NTSB found that the crew's use of reverse thrust greater than 1.3 EPR was a contributing factor to the accident (NTSB 2001). The safety recommendations asked the FAA to do the following:

> Issue a flight standards information bulletin that requires the use of 1.3 engine pressure ratio as the maximum reverse thrust power for MD-80 series airplanes under wet or slippery runway conditions, except in an emergency in which directional control can be sacrificed for decreased stopping distance. (A-01-51)
>
> Require principal operations inspectors of all operators of MD-80 series airplanes to review and determine that these operators' flight manuals and training programs contain information on the decrease in rudder effectiveness when reverse thrust power in excess of 1.3 engine pressure ratio is applied. (A-01-52)
>
> Require all operators of MD-80 series airplanes to require a callout if reverse thrust power exceeds the operators' specific engine pressure ratio settings. (A-01-53)

Regarding Safety Recommendations A-01-51 and -52, on December 18, 2002, the FAA stated that it issued a memorandum to all Part 121 principal operations inspectors (POI) who had direct responsibility for MD-80 airplanes. The POIs were specifically directed to call attention to Boeing's recommended maximum of 1.3 EPR in reverse thrust during landings with wet or slippery runway conditions except in an emergency for which directional control could be sacrificed for decreased stopping distance. The POIs were also directed to emphasize the importance of including the manufacturer's recommended maximum of 1.3 EPR in the training program and flight manuals used by their operator's flight crews. On May 6, 2003, the NTSB stated that the FAA's actions met the intent of Safety Recommendations A-01-51 and -52; as a result, the recommendations were classified "Closed—Acceptable Action."

Regarding A-01-53, on February 4, 2003, the FAA stated that Boeing included a procedure in its MD-80 *Flight Crew Operating Manual* to have the PM make a callout any time that the manufacturer's specific reverse power EPR was exceeded. On May 6, 2003, the NTSB classified this recommendation "Closed—Acceptable Action."

#### 1.10.3.2 Landing Performance

On October 16, 2007, the NTSB issued Safety Recommendations A-07-63 and -64 as a result of the December 2005 accident involving Southwest Airlines flight 1248 (discussed in section 1.10.2).[67] The safety recommendations asked the FAA to do the following:

> Establish a minimum standard for 14 *Code of Federal Regulations* Part 121 and 135 operators to use in correlating an airplane's braking ability to braking action reports and runway contaminant type and depth reports for runway surface conditions worse than bare and dry. (A-07-63)
>
> Demonstrate the technical and operational feasibility of outfitting transport-category airplanes with equipment and procedures required to routinely calculate, record, and convey the airplane braking ability required and/or available to slow or stop the airplane during the landing roll. If feasible, require operators of transport-category airplanes to incorporate use of such equipment and related procedures into their operations. (A-07-64)

Regarding A-07-63, on October 28, 2014, the FAA stated that, as a result of the TALPA ARC recommendations, many document changes would be forthcoming. For example, the FAA planned to incorporate the information from SAFO 06012, "Landing Performance Assessments at Time of Arrival (Turbojets)," which was issued on August 31, 2006, into several ACs, the *Aeronautical Information Manual*, NOTAMs, and ATC and airport guidance and manuals by October 2016. In addition, the FAA stated that it was developing the RCAM tool. The FAA indicated that the RCAM "takes a known assessment criteria provided from the airport and provides the pilot with a downgrade assessment criterion," which would be based on the reported runway conditions, including the reported runway friction (expressed as a Mu value) and the reported braking action. The FAA also indicated that this information would provide a pilot with an expected braking ability to slow or stop the airplane during the landing roll.

On February 10, 2015, the NTSB noted that the development and testing of the RCAM was nearing completion and that, during a December 2014, teleconference, the FAA indicated its intention to mandate the use of the RCAM once completed.[68] Safety Recommendation A-07-63 remained classified "Open—Acceptable Response" pending completion of the RCAM and the requirement for its use by all appropriate airports and operators.

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[67] The NTSB issued five other recommendations (A-07-58 through -62) as part of the flight 1248 investigation. The NTSB's letter for Safety Recommendations A-07-58 through -64 can be found by accessing the Safety Recommendations link on the NTSB's Aviation Information Resources webpage.

[68] The FAA planned to mandate the use of the RCAM through changes to the electronic forms that airports use to populate runway condition information in the NOTAM system. In addition, information provided at the FAA's industry-wide rollout for the TALPA program stated that "all certificated airports and federally obligated airports are required to meet the requirements for generating [RCAM runway condition codes]. The effort is voluntary for all other airports."

Regarding A-07-64, on August 29, 2012, the FAA stated that some airplane manufacturers offered products that calculate and convey the braking ability required and/or available to slow or stop the airplane during the landing roll. The FAA also stated that other manufacturers were developing programs that would report braking action to air carrier dispatch centers to determine real-time braking performance. The FAA planned to encourage the use of such programs and products on a voluntary basis but did not plan to mandate their use. Further, the FAA stated that it no longer planned to conduct a research project to demonstrate the feasibility of these systems because they were "becoming commercially available." On December 26, 2012, the NTSB replied that it was pleased to learn about industry efforts to develop the recommended system and stated that the FAA should require, if feasible, such commercially available systems. On May 9, 2014, the FAA stated that it encouraged the use of commercially available systems that routinely calculate, record, and convey airplane braking ability but maintained its position not to mandate the use of such systems.[69]

On July 24, 2014, the NTSB stated that the commercial systems that were available at that time were not sufficient to satisfy the intent of this recommendation. The NTSB also stated that it had recently learned that the Commercial Aviation Safety Team (CAST) was conducting research and development on the recommended systems.[70] The CAST project appeared to address the first action specified in Safety Recommendation A-07-64 (demonstrate the feasibility of systems that routinely calculate, record, and convey the airplane braking ability required and/or available to slow or stop the airplane during the landing roll).[71] The NTSB further stated that the CAST project demonstrates that it is "premature to conclude that these systems are fully developed and available." In addition, the NTSB expressed its disappointment that the FAA had not previously provided information to the NTSB about the CAST project given that the FAA was an active participant in the CAST.[72]

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[69] According to the FAA's October 28, 2014, letter in response to Safety Recommendation A-07-63, the commercially available systems included Airbus' Runway Overrun Prevention System, which Airbus planned to release to competing aircraft builders to protect against runway overruns by those aircraft, and Aviation Safety Technologies LLC's SafeLand software system, which reports braking action to an air carrier's dispatch center.

[70] According to an April 2016 FAA fact sheet, the CAST examines accident data to detect risk and implement mitigation strategies to prevent future accidents and incidents. The fact sheet also stated that the CAST's goal for the next decade is "to transition to prognostic safety analysis."

[71] This project is "SE [Safety Enhancement] 222: Runway Excursion – Airplane-based Runway Friction Measurement and Reporting" (accessed September 1, 2016). In the July 2014 response to the FAA, the NTSB expressed its belief that "when the CAST completes its related work, the recommended systems will be available, and it is likely that most operators will equip their fleets with these systems."

[72] During the investigation of this accident, the NTSB learned of other FAA activities to demonstrate the feasibility of equipping transport-category airplanes with a system to calculate, record, and convey airplane braking ability. For example, on January 30, 2013, the FAA published a broad agency announcement (soliciting technical work) titled "Determining Runway Friction Conditions in Real-Time Using Data Obtained from Airplanes during the Landing Rollout." Also, two private organizations briefed the NTSB on products that they were developing, in cooperation with the FAA, to derive an airplane's braking ability from information collected during the landing roll. The FAA had not provided the NTSB with information about these activities in correspondence related to Safety Recommendation A-07-64.

The NTSB also expressed concern that, if the FAA did not act on the second part of Safety Recommendation A-07-64 (to require such systems if feasible), and operators equipped their fleets with the recommended system (once developed) on a voluntary basis, the "greatly improved runway condition data" collected by such systems would be available solely to the operators and not to others that need this information, such as ATC, airport operators, or airplanes operated by other organizations. As a result, Safety Recommendation A-07-64 remained classified "Open—Acceptable Response" pending completion of the CAST project and FAA actions to ensure that the data would be available to organizations outside of air carriers with a safety need for the information.[73]

As previously stated, on June 9, 2016, the FAA held an industry-wide rollout for the TALPA program. The NTSB notes that the information provided at the briefing regarding the development and planned use of the RCAM would address the requested action in Safety Recommendation A-07-63. The NTSB also notes that none of the information provided at the briefing addressed the requested action in Safety Recommendation A-07-64. In addition, although the CAST is continuing to conduct research and development on systems in response to Safety Recommendation A-07-64, the NTSB is not aware of any system that has fully demonstrated the technical and operational feasibility of equipping transport-category airplanes with such a system.

#### 1.10.3.3 Communication and Coordination Among Flight and Cabin Crews

On May 19, 2009, the NTSB issued Safety Recommendation A-09-27 as a result of its investigation of the September 28, 2007, accident involving American Airlines flight 1400, an MD-82 that experienced an in-flight engine fire during a departure climb from STL and made a successful emergency landing on one of the airport's runways. The NTSB found that, during the emergency situation, the flight attendants did not relay potentially pertinent information to the captain in accordance with company guidance and training. In addition, the NTSB found that the flight crew considered initiating an evacuation but did not establish communication with the cabin crew to obtain and exchange information (NTSB 2009).[74] Safety Recommendation A-09-27 asked the FAA to do the following:

> Revise Advisory Circular 120-48, "Communication and Coordination Between Flight Crewmembers and Flight Attendants," to update guidance and training provided to flight and cabin crews regarding communications during emergency and unusual situations to reflect current industry knowledge based on research

[73] The NTSB initially classified Safety Recommendations A-07-63 and -64 "Open—Acceptable Response" on June 13, 2008.

[74] After a discussion with ARFF personnel, the flight crew decided not to evacuate, but the ARFF incident commander decided to deplane the passengers about 30 minutes later after heat and smoke were observed coming out of a damaged engine.

> and lessons learned from relevant accidents and incidents over the last 20 years.[75]

On August 28, 2012, the FAA stated that its supplemental notice of proposed rulemaking (SNPRM), "Qualification, Service, and Use of Crewmembers and Aircraft Dispatchers," addressed this recommendation by requiring that initial and recurrent flight and cabin crew training include communication during emergency situations (NARA 2011). The FAA also stated that it was revising AC 120-48 to update the guidance regarding communications during emergency and unusual situations to reflect current industry knowledge based on lessons learned. The FAA indicated that it anticipated issuing the revised AC in 2013.

On March 18, 2014, the NTSB stated that the final rule resulting from the SNPRM did not contain the action addressed in this recommendation but noted that the recommended action could be accomplished outside of the final rule (NARA 2013). The NTSB also stated that, according to its conversations with the FAA, the issuance of revised AC 120-48 was delayed by work associated with the final rule, but the FAA indicated that it still intended to issue the revised AC 120-48. As a result, Safety Recommendation A-09-27 remained classified "Open—Acceptable Response" pending completion of that action.[76]

[75] The NTSB noted that this AC had not been updated since its issuance in July 1988 and thus did not reflect industry knowledge that was current at the time that the safety recommendation was issued.

[76] Safety Recommendation A-09-27 was initially classified "Open—Acceptable Response" on April 2, 2010.

# 2. Analysis

## 2.1 Accident Sequence

### 2.1.1 General

The flight crew was properly certificated and qualified in accordance with federal regulations and company requirements. Flight crew fatigue was likely not a factor in this accident.[77] The airplane was properly certificated, equipped, and maintained in accordance with federal regulations. No evidence indicated any preimpact structural, engine, or system failures.

### 2.1.2 Preflight Activities

A major winter storm was impacting the northeastern United States on the day of the accident, with a significant accumulation of snow expected in the New York area. The flight crewmembers were aware of the storm, and they began preparing for the flight to LGA after arriving in ATL at 0705. While at the departure gate, the crewmembers reviewed information regarding the expected conditions at the time of landing, including Delta's terminal forecast for the planned arrival time (1055), which indicated that visibility would be 1/2 mile in moderate snow and mist with a broken ceiling at 700 feet agl and 4 to 7 inches of snow expected. The forecasted conditions were expected through 1200 that day.[78] The flight crew also reviewed a NOTAM issued at 0445 that indicated that the runways were wet and had been sanded and deiced with solid chemical. (A more recent NOTAM, issued at 0738, was not part of the 0740 company weather package provided to the flight crew; that NOTAM reported that runway 13 was covered with thin, wet snow.) In addition, the flight crew reviewed the ATIS information issued at 0751 (Lima) and 0851 (Mike).[79] ATIS information Lima and Mike both reported that

[77] The captain reported needing 8 to 9 hours of sleep per night to feel rested, so he had a cumulative sleep deficit of 3 to 3.5 hours (see table 2) during the 72 hours preceding the accident. The first officer reported needing 7.5 hours of sleep per night to feel rested, so he had a cumulative sleep deficit of about 2 hours (see table 3) during that period. Research indicated that such sleep deficits could result in very small performance-related effects (Belenky and others 2003). However, these minor effects would likely have been offset by circadian factors that promote alertness during the late morning hours (when the accident occurred). In addition, at the time of the accident, the flight crew had not been on duty excessively long (about 6 hours including the accident flight), flown multiple trip legs (the accident flight was the second leg of the day), or been awake for a long time (about 7.5 hours for the captain and 7 hours for the first officer).

[78] Although no deficiencies were noted in Delta's weather documentation, the company's meteorology department did not anticipate the low IFR conditions or 1/4-mile visibility during the period and the heavy snow that occurred immediately after the accident.

[79] ATIS information Mike reported 1/2-mile visibility with snow and freezing fog. Title 14 *CFR* 121.613 prohibits the dispatch of a flight operating under IFR unless appropriate weather reports or forecasts, or any combination thereof, indicate that the weather conditions will be at or above the authorized minimums at the estimated time of arrival. The minimum visibility for an instrument approach to runway 13 at LGA was 1/2 mile; thus, at the time of dispatch, the forecasted visibility for LGA was at the required minimum visibility.

the runways were wet and had been sanded and deiced with solid chemical, which was not current given the report of thin, wet snow in the 0738 NOTAM.

The flight was dispatched according to 14 *CFR* 121.195.[80] Dispatch calculations indicated that the landing distance would be 5,995 feet (based on a planned landing weight of 132,500 pounds, flaps 40, a 15% safety margin for a wet runway, and maximum braking). The operational landing distance assessment, which included the use of maximum autobrakes with good braking action and reverse thrust (among other factors), was 6,200 feet—about 800 feet less than the available length of runway 13. Thus, the information that the flight crew had at the time of departure showed that the airplane would be able to safely stop on the runway.

### 2.1.3 En Route Preparations and Decision-making

After the airplane departed ATL (about 0924), the flight crew continued to monitor the weather conditions at LGA and assessed the factors that could affect stopping performance. While in cruise flight at 0954:52, the flight crew consulted Delta's contaminated runway crosswind limitations and recognized that the crosswind would be at Delta's 10-knot limit if the runway braking action was reported to be medium/poor. The flight crew then requested, via ACARS, a field condition report from the dispatcher. The report indicated that braking action advisories were in effect but that no braking action reports were available.

At 1005, the flight crew discussed the effect of moderate snow on visibility. Beginning at 1010:35, the crew discussed the landing distance using flaps 40, a 130,000-pound landing weight (which was less than the preflight planned landing weight due to fuel burn), and medium braking action. The flight crew recognized that the airplane would not be able to land with medium/fair braking action because the calculated landing distance for maximum autobrakes (7,800 feet) and maximum manual braking (7,200 feet) would exceed the available runway 13 length of 7,003 feet.[81] As a result, the flight crew relayed information to the dispatcher indicating that the airplane could only land with good braking action. The flight crew also asked the dispatcher (at 1018) and the Washington ARTCC controller (at 1027) for braking action reports, but neither had any reports at the time to provide the crew because LGA operations personnel had been conducting snow removal operations on runway 13/31 (between 1006 and 1035) and no airplanes were landing.

After the Washington ARTCC controller advised the flight crew that the airplane would be holding at the Robbinsville VOR because of runway cleanup, the captain expressed frustration

[80] The dispatch release showed a planned fuel load (29,600 pounds) that was in excess of the required fuel load (about 26,000 pounds) to allow the flight crew to hold the airplane for an extended period or divert to one of the two designated alternate airports if necessary. However, the extra fuel would also increase the planned landing weight if holding or diverting was not necessary.

[81] As previously stated, the landing performance data in Delta's *Operational Data Manual* assumed a 1,500-foot air distance and a safety factor of 15%. These data are conservative to account for any uncertainty regarding the landing. As a result, the flight crew's landing distance assessment showed that medium braking action would result in an insufficient stopping distance. However, the NTSB's aircraft performance study showed that medium braking action conditions were present when the previous Delta MD-88 successfully stopped on runway 13.

to the first officer that company dispatch had not alerted them about the possibility of holding. The captain then asked the first officer if he had received any braking action reports from the controller. After the first officer replied that he had not yet received any reports, the captain repeated his frustration about dispatch's lack of advanced notice about holding and expressed further frustration about the lack of timely braking action reports from ATC and dispatch (before the runway was closed for snow removal operations). The NTSB concludes that the flight crewmembers' uncertainty about the runway conditions at LGA led to some situational stress for the captain.

At 1045:38, the accident flight crewmembers heard a controller at the New York TRACON advise a flight crew of a poor braking action report for runway 13. The captain told the first officer "we can't land with poor." Shortly afterward, the controller advised another flight crew that an Airbus airplane had reported good braking action on runway 13. Afterward, the flight crew of a regional jet also reported that the braking action on runway 13 was good. During postaccident interviews, the accident captain recalled thinking that two reports indicating good braking action meant that conditions were adequate to proceed with the approach, and the accident first officer recalled thinking that two consecutive reports of good braking action were a "green light" to continue.

ATIS information Quebec (issued at 1051) indicated that 1/4 inch of wet snow was observed on the runways at 0904 and that "all runways are wet and have been sanded and deiced with solid chemical."[82] However, the most recent NOTAMs at the time (issued at 0902 and 0903) reported that 1/4 inch of wet snow was on the runways but did not indicate that the runways had been treated. Further, according to radio communications between ATC and the LGA snow coordinator, about 1038 the snow coordinator reported to the local controller that "the runways have not been treated" and that "we're just brooming and plowing."[83] (The flight crew did not know the information reported by the snow coordinator.) Thus, the ATIS report that was current at the time of the accident (Quebec), as well as the four previous ATIS reports (Lima, Mike, Oscar, and Papa, issued between 0751 and 1024), contained outdated and contradictory field condition information about the status of LGA's runways.

Because braking action reports are subjective, the captain attempted to assess the reliability of the reports indicating good braking action.[84] At 1055:34, he asked the first officer, "wonder who reported braking action good? That's another concern of mine," to which the first officer replied, "it was United." During a postaccident interview, the captain stated that he had confidence in this and the subsequent report of good braking action, which was likely because the reports were made by flight crews of other passenger jets operated by Part 121 air carriers.

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[82] According to the runway condition/braking action chart in Delta's *Operational Data Manual,* a wet runway was expected to have good braking action.

[83] During a postaccident interview, the LGA snow coordinator stated that the snow crews were not applying chemical to the runways at that point because snow had begun to accumulate and any application of chemical would have been immediately broomed, plowed, or blown off, reducing the chemical's effectiveness.

[84] SAFO 06012 indicated that a "reliable" braking action report would be "submitted from a turbojet airplane with landing performance capabilities similar to those of the airplane being operated."

The flight crewmembers knew that, during a winter storm, changes to wind, visibility, or braking action could affect landing performance. They discussed that moderate snowfall could reduce visibility at the airport. They closely examined company policies for landing on contaminated runways and understood that a change in runway conditions from accumulating snowfall could increase the landing distance and that a change in wind could cause the flight to exceed crosswind limits. The NTSB concludes that the flight crew was well prepared for the approach and established landing requirements that were consistent with company policies.

### 2.1.4 The Approach

At 1058:41, the controller cleared the flight for the ILS approach to runway 13. Shortly afterward, the controller told the flight crew that the RVR for runway 13 was greater than 6,000 feet, with a rollout RVR of 4,000 feet.[85] At 1059:54 (about 2.5 minutes before landing), the captain told the first officer to ask the controller for a wind check because of the captain's concerns regarding a "pretty good tailwind" on approach.[86] The controller reported that the wind was from 020º at 10 knots. At that point, the tailwind component was about 4 knots, which was less than Delta's 10-knot limit, and the crosswind component was about 9 knots, which was less than Delta's guidelines for medium/poor runway conditions.

The captain decided to continue the approach to a landing because he and the first officer had determined that the landing criteria had been met, including the landing distance performance requirements for good braking action. The captain called the runway in sight as the airplane descended through an altitude of about 233 feet agl. Besides company and ATIS reports indicating that the runway was plowed, sanded, and chemically treated and was wet with snow, the flight crew had overheard ATC stating, as late as 1040, that arriving airplanes were being held for runway cleanup. The first officer stated that these communications "painted a picture" of what he and the captain could expect to see once the airplane broke out of the clouds—a runway that had at least some patches of runway surface visible. However, the captain and the first officer reported that the runway appeared white rather than dark or patchy, which was not

[85] ATIS information Quebec (which was current at the time) reported the visibility as 1/4 mile, which was below the 1/2-mile visibility required for the approach. However, the approach could still be performed because the RVR was above 2,400 feet.

[86] Before final approach, the flight crew had not discussed the possible effects that a tailwind could have on landing performance. One explanation for that could be that, at the time that the captain conducted the approach briefing, the reported wind (from ATIS information Papa) was from 040º at 7 knots, resulting in a direct crosswind (90º) for runway 13 with no tailwind component. Another explanation could be that Delta's training program did not include instruction on landing with a tailwind and that the company's MD-88 adverse weather operating procedures did not provide guidance for landing with a tailwind on a contaminated runway.

consistent with their expectations regarding the nature and extent of the contamination on the runway given the recent snow cleaning operations and the reports of good braking action.[87]

Delta's MD-88/90 operating procedures for adverse weather indicated that, "when there is contamination on the runway…captains must evaluate crew, aircraft, and environmental conditions in determining the safety of operating their flight." Key environmental conditions included braking action reports, the nature of contamination (water, wet snow, or dry snow), and the depth of the contamination. The flight crew knew that two preceding airplanes had reported good braking action on the runway. However, it would have been difficult for the crew to visually assess the nature and depth of the snow on the runway.[88] Also, little time was available for the flight crew to reevaluate the decision to continue. Only 13 seconds had elapsed between the time that the captain called the runway in sight and the time of the 50-foot automated callout, when the captain would have been preparing to flare the airplane. During these 13 seconds, the captain was engaged in several tasks, including adjusting the aim point to land closer to the approach end of the runway, decrabbing the airplane to align its longitudinal axis with the runway, and making aileron inputs to correct for drift. The NTSB concludes that, even though the flight crewmembers' observations of snow on the runway were inconsistent with the expectations that they formed based on the field condition information that they received, their decision to continue the approach was not inappropriate because the landing criteria had been met.

### 2.1.5 The Landing

The airplane touched down about 17 seconds after the captain called the runway in sight. During the 27 minutes between the time that runway 13 was last cleared of snow and the landing, snow continued to fall, with fresh snow covering the runway. As previously stated, the 0903 NOTAM, which was current at the time of the accident, reported 1/4 inch of wet snow on runway 13. The NOTAM was issued more than 1.5 hours before runway 13 was last cleared of snow (as discussed further in section 2.6.2); however, given the amount of time between the last runway clearing and the landing and the likely amount of snow that had accumulated during that time, the NOTAM likely described the approximate depth of the contamination on the runway surface at the time of the airplane's landing.

The accident airplane was the fifth arrival on runway 13 after it was last cleared. During this time, one report of medium braking action at the touchdown zone was received about

[87] Although the flight crewmembers reported, after the accident, that the appearance of the runway was not what they expected based on the field condition information, the CVR showed that they did not consider that the snow that was falling could alter the landing performance calculations or that the braking conditions might have deteriorated from the good braking action reported by the flights crews of two airplanes that had recently landed on runway 13. However, the flight crew was not required to perform a go-around maneuver because the landing criteria were met and, as shown by FDR and radar data, the captain flew a stabilized approach.

[88] Company landing criteria indicated that landing was not permitted with a snow depth of 1 inch or greater. Given the recent reports of good braking action on runway 13, the flight crew had no information that would have specifically prohibited the landing.

19 minutes before the accident landing, and reports of good braking action were received about 16 and 8 minutes before the accident landing.[89] Because braking action reports are inherently subjective, the NTSB considered the results of the simulations it conducted with Boeing as part of this accident investigation. The simulations showed that the wheel braking coefficient for the accident airplane was, at a minimum, consistent with the description of medium braking action in AC 25-32 and that the Delta MD-88 that landed uneventfully on runway 13 just before the accident landing had a similar wheel braking coefficient.[90] In addition, the flight crew of the MD-88 airplane that landed on runway 13 just before the accident landing did not report any adverse landing conditions. Thus, the NTSB concludes that, although the runway was contaminated with snow, runway friction when the accident airplane landed was sufficient for stopping on the available runway length.

For several seconds after touchdown, the airplane's heading tracked with the runway centerline, indicating that the captain's initial control inputs were sufficient to maintain directional control of the airplane. However, a combination of the 9-knot left crosswind component and asymmetric reverse thrust inputs (described below), as well as possible differences in runway friction for the left and right main landing gear, induced a left yawing moment after the airplane was on the runway.[91] Under normal circumstances, this left yawing moment would be controllable through the use of right rudder pedal inputs, but, about 6 seconds after touchdown, the airplane's heading began to deviate to the left from 131º, reaching 114º (20º off the runway's magnetic heading of 134º) 6 seconds later.

Reverse thrust is one method for decelerating the airplane on slippery runways, and it is most effective at high speeds. Delta's *Flight Crew Training Manual* instructed MD-88 pilots to "activate reverse thrust with as little time delay as possible." However, the manual also indicated that, when landing on a contaminated runway, MD-88 pilots should consider delaying thrust reverser deployment until nosewheel touchdown so that directional control would not be affected by asymmetric deployment.

The captain deployed the thrust reversers almost simultaneously with the main landing gear touchdown. He reported that he had moved the thrust reverse levers back "one knob width on the reverser handle" to achieve Delta's recommended target of 1.3 EPR on contaminated

89 As previously stated, the flight crew that reported medium braking action at the touchdown zone also reported poor braking conditions farther down the runway. The accident flight crew was not aware of the medium braking action report from that flight crew but had overheard the controller at the New York TRACON advising another flight crew of the poor braking action conditions.

90 The airport RCAM as of June 2016 (see figure 5), which airports were not expected to use until October 2016, would have categorized the braking action on runway 13 at the time of the accident landing as medium (given the 1/4 inch of wet snow reported in the 0903 NOTAM).

91 According to the FAA's *Airplane Flying Handbook* (FAA-H-8083-3A), during the roll after a crosswind landing, the wind acting on the airplane will have a "weathervaning" effect. The handbook also stated that "the greater the crosswind component, the more difficult it is to prevent weathervaning."

runways.[92] After this reverse thrust input, the EPR on both engines began to increase rapidly. FDR data showed that the left engine reverse thrust increased faster than that on the right engine (resulting in asymmetric reverse thrust).[93] Further, the left engine reverse thrust increased from 1.3 to 1.6 EPR (the target setting for landing on dry runways) in 0.5 second. The NTSB's review of data from 35 Delta MD-88 landings with at least one engine above 1.6 EPR showed that the average time between 1.3 and 1.6 EPR was about 1.25 seconds. Thus, the reverse thrust during the accident landing increased more rapidly than it did during the other landings, indicating that the captain's input on the thrust reverser handles was relatively aggressive.

It is possible that the captain had developed a habit of applying more reverse thrust than 1.3 EPR. Because most landings are performed on dry runways, Delta pilots, including the accident captain, were accustomed to using 1.6 EPR reverse thrust (or greater) after such landings. At landing and initial rollout speeds, the rudder should generate enough aerodynamic force to control the direction of the airplane. On a dry runway with an average wind, the rudder blanking that results from high reverse thrust is not significant because high frictional forces between the tires and the runway maintain the airplane's direction during the landing roll. However, during the accident landing, directional control of the airplane was affected by the disruption of airflow resulting from the high reverse thrust (which reached maximum values of 2.07 EPR on the left engine and 1.91 EPR on the right engine) and the runway friction, which, although sufficient, was limited. In addition, the higher reverse thrust on the left engine would tend to yaw the airplane to the left.

Even though all Delta MD-88 pilots had been instructed to target 1.3 EPR on contaminated runways and practiced targeting that reverse thrust setting during simulator training, a habit of using more than 1.3 EPR might have prevailed when the captain was faced with the demands of the landing on the day of the accident. Situational factors associated with the landing also likely affected the timing and magnitude of the captain's reverse thrust input. The captain knew that the conditions could be marginal for landing on runway 13 and that the landing would require most of the runway for the airplane to stop given the conditions and the airplane's landing weight. In addition, the captain likely perceived the snowier-than-expected runway as a threat that, along with the relatively short runway, could impede his ability to stop the airplane within the available runway length. These factors, as well as runway 13's nonstandard runway safety area and the presence of Flushing Bay directly off the departure end of the runway, likely compounded the captain's previous stress resulting from the unavailability

[92] The FDR did not record reverser handle position, so it is not possible to determine the captain's actual input. During a postaccident interview, the captain stated that he would normally "tweak" the thrust reversers after his initial input to obtain the target EPR setting, but FDR data showed that he did not adjust the thrust reverse settings until the first officer's callouts to come out of reverse.

[93] The reviewed Delta MD-88 landing data showed that such asymmetry commonly occurred during the application of reverse thrust.

of braking action reports during the en route and descent phases of flight.[94] The NTSB concludes that the circumstances associated with the landing, including the snowier-than-expected runway, short runway length, and body of water off the departure end of the runway, likely exacerbated the captain's situational stress and prompted him to make an aggressive input on the thrust reversers.

The captain recalled that, immediately after his application of reverse thrust, the airplane began sliding to the left, which caused him to focus his attention outside of the airplane and at the high snowbanks along the runway. The captain (and the first officer) then sensed an absence of deceleration from the autobrakes, which drew the captain's attention back inside the airplane so that he could verify that the spoiler handle was in the deployed position (a necessary action for the autobrakes to engage).[95]

The captain stated that, after he verified that the spoilers had deployed, he assumed that the autobrakes were not gripping. The captain also stated that, although he was concerned about the braking action, he had confidence in the ability of the autobrakes to achieve maximum braking for the available friction, so he did not immediately switch to manual braking. The captain further stated that he felt the airplane continue to slide to the left and that his efforts to counteract the slide with the rudder pedals were the primary focus of his attention at that point. However, the captain reported that the airplane did not respond to his efforts to steer back to the right.

As the captain applied right rudder, the first officer made the "two in reverse" callout. The airplane's heading then began to move to the left in response to the yawing moment. About 1.5 seconds after the first officer made the 110-knot callout and in response to the airplane's change in heading, the first officer began calling for the captain to take the thrust levers out of reverse, stating (over a 1.5-second period) "out of reverse," "come out of reverse," and then in a louder voice "come out of reverse."[96] Although the first officer had not seen or heard indications of high reverse thrust, he suspected that rudder blanking (due to excessive EPR and the subsequent loss of rudder effectiveness) was the reason that the captain was unable to counteract

[94] A standard runway safety area is 1,000 feet long by 500 feet wide, but some airports, including LGA, have nonstandard runway safety areas due to geographic or other limitations. The runway safety area at the approach end of runway 13 is 90 feet long and 150 feet wide. The runway safety area at the approach end of runway 31 (the departure end of runway 13) is 460 feet long by 500 feet wide. An engineered materials arresting system is in place at the departure end of runway 13.

[95] As previously indicated, FDR data showed that the autobrakes activated almost simultaneously with the increase in reverse thrust. FDR data also showed that spoiler deployment occurred at the same time as thrust reverser deployment. The first officer indicated that he manually activated the ground spoilers because they did not automatically activate immediately. A postaccident examination of the spoiler system found no anomalies; thus, during the initial touchdown, the autospoiler actuator most likely did not activate immediately upon landing because the main landing gear wheels had not yet spun up to the necessary rotation speed. Less than 1 second after manually activating the spoilers, the first officer made the "spoilers up" callout.

[96] At the time of the first officer's "out of reverse" announcement, the left engine had reached 1.9 EPR, and the right engine had reached 1.8 EPR.

the unexpected left yaw.[97] In crew resource management (CRM) terms, the first officer's persistent and vigorous attempts to communicate a possible reverse thrust exceedance and the need to correct it were examples of effective advocacy and assertion.[98]

During the period when the first officer was telling the captain to come out of reverse thrust due to the left yaw, the captain was likely experiencing a phenomenon known as "attentional tunneling," which refers to the tendency for humans, when highly stressed, to become preoccupied with salient (or threatening) primary cues and ignore potentially important peripheral information (Staal 2004). The captain stated that he was not able to monitor the EPR gauges (after noticing that reverse thrust was initially increasing uniformly) because he had to direct his attention to "multiple distractions" during the landing roll: the slide to the left immediately after the application of reverse thrust, concern that the autobrakes were not working (causing him to check the spoiler handle), and the continuing slide to the left despite efforts to steer the airplane away from the snowbanks alongside the runway.

FDR data showed that the captain responded to the first officer's callouts to come out of reverse thrust between 2.5 and 3.5 seconds after the onset of the callouts (and 4.5 to 5.5 seconds after the onset of the left yaw). The captain's response time was within the expected range for an operator responding to an unexpected, dynamic event under conditions of high workload, stress, and divided attention. As the captain stowed the thrust reversers and applied substantial right rudder, right nosewheel steering, and right manual braking, the left yawing motion slowed, but the airplane's heading was already 12º off the runway centerline. The NTSB concludes that the captain was unable to maintain directional control of the airplane due to rudder blanking, which resulted from his application of excessive reverse thrust. The NTSB also concludes that, even though the first officer promptly identified rudder blanking as a concern and the captain stowed the thrust reversers in response, the airplane's departure from the left side of the runway could not be avoided because directional control was regained too late to be effective.

## 2.2 Mitigations to Preclude Excessive Reverse Thrust Use

### 2.2.1 Flight Crew Training and Procedures

In February 1996, McDonnell Douglas issued All Operators Letter FO AOL-9-058, which discussed MD-80 handling characteristics on wet or slippery runways. The letter stated the manufacturer's intent to change recommended procedures for the MD-80, including the reverse thrust to be used when landing on wet or slippery runways. The MD-80 *Flight Crew Operating Manual* was subsequently revised to recommend limiting reverse thrust on contaminated

[97] The first officer had flown the E2C Hawkeye in the US Navy for 18 years. The first officer indicated the E2C airplane had rudder blanking issues, so he was familiar with that phenomenon. The first officer described the sound of high reverse thrust as an "overboost."

[98] FAA AC 120-51E, "Crew Resource Management Training," dated January 22, 2004, described the CRM behaviors "inquiry/advocacy/assertion" as "advocating the course of action that [crewmembers] feel is best, even though it may involve conflict with others."

runways to 1.3 EPR.[99] The revision did not establish this procedure as an airplane limitation, which would have required operator compliance, so operators could choose to incorporate the guidance in the manual or develop their own procedures. Delta chose to emphasize, in its flight crew training and procedures, targeting a reverse thrust setting of 1.3 EPR when landing on contaminated runways and 1.6 EPR when landing on dry runways.

Even with the snow contamination on runway 13 on the day of the accident, the FDRs on both the accident flight and the flight by the preceding Delta MD-88 that landed at LGA recorded maximum EPR values that exceeded 1.6 (2.07 EPR and 1.80 EPR, respectively). The NTSB's review of data from 80 landings made by two Delta MD-88 airplanes showed that all 14 flights that landed with precipitation (according to archived airport weather observations) exceeded 1.3 EPR during landing and that one-half of those flights exceeded 1.6 EPR in at least one engine. The EPR levels during the accident flight (2.07 on the left engine and 1.91 on the right engine) were higher than all EPR levels in the landing data reviewed. In addition, data from the 80 landings showed exceedances of 1.6 EPR in more than one-third of those landings.[100]

One possibility for the exceedances of published EPR settings that were observed in Delta's data is that conditions that are supposed to prompt MD-88 flight crews to use smaller amounts of reverse thrust might actually prompt the crews to make reverse thrust inputs that are larger than usual. During the accident landing, the runway was contaminated, and braking action advisories were in effect. In such situations, pilots might use higher amounts of reverse thrust because they are more concerned about their ability to stop an airplane within the available runway distance than they are about the risk of a loss of directional control. Also, pilots with a habit of routinely using more reverse thrust than needed might lack an awareness of the risks of EPR exceedances because such exceedances rarely result in any adverse outcomes.

Another possibility for the exceedances of published EPR settings is that competing demands for the flight crews' attention during landing might result in difficulties adhering to EPR targets despite efforts to do so. Landing is a high-workload phase of flight during which crews make required control inputs based largely on visual information acquired from inside and outside of the cockpit. After initially moving the thrust reverser handles, the PF must periodically examine the EPR gauges while steering the airplane down the runway and then adjust the reverser handles as needed in response to observed engine indications.[101] Steering the airplane and monitoring the EPR gauges compete for the same visual and cognitive resources, which can

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[99] Boeing's MD-80 *Flight Crew Operating Manual*, volume II, "Operating Procedures," dated May 15, 2014, cautioned that 1.3 EPR reverse thrust was the maximum that should be applied on wet, slippery, or contaminated runways. The manual also indicated that 1.6 EPR reverse thrust was the maximum for dry runways except in an emergency.

[100] Of the 11 MD-80 runway excursions (over a 20-year period) that are identified in table 7, reverse thrust exceeded 1.3 EPR during eight of the events, all of which involved runway contamination. Of those eight events, five involved reverse thrust at or above 1.6 EPR.

[101] Because the thrust reverser handle position is not recorded by the FDR, the lag in engine spool-up time that occurs during actual operations is not known. The landing data reviewed as part of this investigation indicated that the engine spool-up time could be about 0.5 to 2 seconds.

cause the increased difficulty associated with one task to interfere with the performance of the other task. For example, the airplane steering task can be more difficult in snow conditions because of the challenges associated with discriminating key features of the runway environment. This situation would tend to increase the time allocated to acquiring information outside the cockpit and consequently degrade the effectiveness of the flight crew's monitoring of indications (including EPR gauges) inside the cockpit.

The NTSB attempted but was unable to identify any research evaluating the possible explanations (pilot decision-making or pilot perceptual and cognitive limitations) for the large number of EPR exceedances shown in Delta's MD-88 landing data. Regardless of the explanation for such exceedances, Delta MD-88 flight crews were routinely exceeding reverse thrust EPR targets despite company training and procedures on these targets, indicating the need for a more reliable means to limit the maximum reverse thrust that MD-88 flight crews use.

Because EPR exceedances were likely the result of human factors issues associated with operating in high-workload, high-stress situations, including those present during the accident landing, flight crews at other air carriers that operate MD-80 series airplanes might also experience such exceedances. The NTSB concludes that a solution to reliably limit reverse thrust EPR values could benefit all pilots of MD-80 series airplanes. Therefore, the NTSB recommends that the FAA collaborate with Boeing and US operators of MD-80 series airplanes to (1) conduct a study to examine reverse thrust EPR-related operational data, procedures, and training and (2) identify industry-wide best practices that have been shown to be effective in reliably preventing EPR exceedances to mitigate the risks associated with rudder blanking. The NTSB also recommends that the FAA encourage US operators of MD-80 series airplanes to (1) implement the best practices identified in Safety Recommendation A-16-20 and (2) participate in an industry-wide monitoring program to verify the continued effectiveness of those solutions over time.

### 2.2.2 Engine Pressure Ratio Callout

Safety Recommendation A-01-53, which was issued as a result of the NTSB's investigation of the MD-82 accident in Little Rock, Arkansas, asked the FAA to "require all operators of MD-80 series airplanes to require a callout if reverse thrust power exceeds the operators' specific engine pressure ratio settings." The NTSB classified this recommendation "Closed—Acceptable Action" in May 2003 based on the FAA's statement that Boeing had included a procedure in its MD-80 *Flight Crew Operating Manual* for the PM to make a callout any time a reverse thrust EPR value of 1.3 was exceeded. However, Boeing had issued Flight Operations Bulletin MD-80-02-03 in November 2002, which provided information about rudder blanking (see section 1.3.1) and stated that PM duties "should include monitoring reverse thrust deployment and advising the Pilot-Flying (PF) of excessive EPR settings should they occur." Even though Boeing's bulletin encouraged a procedure in which the PM would notify the PF any time reverse thrust during a landing rollout exceeded the operator's specific EPR settings, each operator of MD-80 series airplanes needed to decide whether to require such a callout.

Delta's *Flight Crew Training Manual* stated that the PM should call out "any engine operational limits being approached or exceeded." However, Delta's procedure did not specifically instruct the PM to make a callout when reverse thrust exceeded 1.3 EPR on a contaminated runway. The Delta MD-88/90 fleet manager stated that both pilots were responsible for monitoring the EPR gauges and that the PM was expected to clearly announce what the EPR gauges displayed.

In this case, the first officer made three callouts (over a 1.5-second period) for the captain to come out of reverse thrust. Although the first officer's callouts resulted in the captain coming out of reverse thrust and eventually regaining directional control of the airplane (even though it was too late to prevent the airplane from departing the runway), the callouts began about 4 seconds after reverse thrust reached 1.3 EPR. Thus, the NTSB still believes in the safety benefit of requiring a 1.3 EPR callout during landings on contaminated runways because of the potential for rudder blanking resulting from EPR exceedances. As a result, the NTSB concludes that a callout when reverse thrust exceeds 1.3 EPR during landings on contaminated runways could help avoid rudder blanking and a subsequent loss of directional control. Therefore, the NTSB recommends that the FAA require operators of MD-80 series airplanes to revise operational procedures to include a callout when reverse thrust power exceeds 1.3 EPR during landings on a contaminated runway.

### 2.2.3 Design Considerations

The operational safety best practices requested in Safety Recommendations A-16-20 and -21 and the 1.3 EPR callout requested in Safety Recommendation A-16-22 are examples of near-term solutions for reducing MD-88 reverse thrust exceedances. A longer-term solution that, according to the FAA's *System Safety Handbook*, could be more effective and reliable would be a design-related change to help prevent or reduce applications of excessive reverse thrust.[102] Design changes can be highly effective in improving overall system performance when limitations of human performance are involved, such as flight crew attentional limitations during the landing rollout.[103]

Because the MD-80 thrust reverser system does not include detents or mechanical limits and the proper control position may vary among MD-80 airplanes due to differences in rigging, flight crews must monitor EPR indications and adjust reverse thrust accordingly. However, as previously discussed, the landing rollout is a high-workload period during which significant visual and cognitive demands are placed on the flight crew. The PF is responsible for simultaneously steering the airplane down the runway and controlling reverse thrust, and the PM

[102] The handbook described the "Safety Order of Precedence" for "eliminating, controlling, or mitigating a hazard." The risk mitigation measure with the largest potential for safety improvements was "design for minimum risk" followed in order by "incorporate safety devices," "provide warning devices," and "develop procedures and training" (FAA 2000).

[103] A study of 460 pilot-reported errors suggested that the design and location of aircraft controls could improve pilot efficiency and reduce the frequency of aircraft accidents. Errors in the adjustment of controls accounted for 18% of errors reported by pilots. Certain adjustment errors were found to occur when pilots were "unable to make a sufficiently precise setting" or did not make "careful and frequent visual checks." For such cases, the report recommended simplification of the procedure for using a control. Forgetting errors (which could include forgetting to check the EPR gauges after making an initial input) made up an additional 18% of the errors reported, and the report suggested that such errors could be reduced by the development of warning devices (Fitts and Jones 1947).

is responsible for monitoring and calling out spoiler deployment, thrust reverser deployment, and airspeed.

Because these tasks need to be concurrently performed in a relatively short period of time, the flight crew cannot continuously monitor EPR indications. As a result, a flight crew's monitoring of EPR indications involves selective attention.[104] When faced with competing task demands, vulnerabilities in selective attention might preclude flight crews from adequately monitoring and controlling reverse thrust during the landing rollout. These vulnerabilities include attentional capture and fixation in response to unexpected, highly salient events that disrupt normal monitoring patterns (for example, the airplane's unexpected slide toward the snowbanks and the captain's perception that the autobrakes were not working).

As stated in section 1.3.1, McDonnell Douglas had developed a design change for MD-80 series airplanes—the installation of a thrust reverser cam with an intermediate detent—to assist flight crews in limiting reverse thrust to 1.3 EPR. McDonnell Douglas later learned that flight crews were experiencing asymmetric applications of reverse thrust and indicated that operators should remove the modification and reinstall an original cam without the detent. However, it is possible that another design solution could prevent EPR exceedances and reduce the risks of rudder blanking and a loss of directional control without introducing unacceptable new hazards. Such a solution could include the development of an automated alert that provides salient aural and visual indications of EPR exceedances.

An automated system could detect an EPR exceedance, provide an active alert to capture the flight crew's attention, and increase the timeliness of a corrective response. Such an alert could also provide feedback to pilots that, over time, could help them become more aware of their habits regarding the use of reverse thrust, which pilots could modify if they were routinely exceeding their operator's specific reverse thrust EPR settings. As a result, the NTSB concludes that an automated alert could help minimize the possibility of reverse thrust EPR exceedances during the landing rollout. Therefore, the NTSB recommends that Boeing explore the possibility of incorporating an alert in MD-80 series airplanes to aid pilots in preventing EPR exceedances.

## 2.3 Technology to Determine Runway Braking Action

As stated in section 2.1.3, the flight crewmembers were frustrated by the unavailability of timely braking action reports during the en route and descent phases of flight and the resulting uncertainty about the runway conditions at LGA, especially given that the airplane could not land with braking action that was less than good. Before the crewmembers began the approach to runway 13, they received two reports indicating good braking action conditions along the

[104] Selective attention is managed (1) through conscious control mechanisms based on expectations about when and where information is likely to appear and how important the information is likely to be and (2) by processes leading to attentional capture (Wickens and McCarley, 2008). The captain's description of his focus during the landing rollout (see section 2.1.5) showed evidence of attentional capture and attentional tunneling.

runway.[105] Postaccident simulations indicated that medium or greater braking action conditions were present at the time that the preceding airplane and the accident airplane touched down. (The flight crew of the preceding airplane did not provide a braking action report after the airplane landed.)

Although the RCAM will provide operators with a framework for more objective runway surface condition reports, the use of airplane-based systems to determine runway surface conditions would be the most objective and timely method for reporting runway conditions to the pilots of arriving aircraft, especially since precipitation, temperature, and traffic can result in continuous changes to runway surface conditions. The NTSB concludes that this accident demonstrates the continuing need for objective, real-time, airplane-derived data about runway braking ability for flight crews preparing to land with runway surface conditions that are worse than bare and dry.

The NTSB issued Safety Recommendations A-07-63 and -64 to address concerns that braking action reports provided by pilots and contaminant type and depth reports provided by airports were inherently subjective and thus not an optimal way to convey reliable information about runway conditions. Safety Recommendation A-07-63 asked the FAA to establish a minimum standard for "correlating an airplane's braking ability to braking action reports and runway contaminant type and depth reports for runway surface conditions worse than bare and dry." The FAA's planned October 1, 2016, implementation of the RCAM would address the action requested in this recommendation because (1) airport operators will have standard criteria for reporting runway surface conditions along each one-third of a runway and (2) airframe manufacturers and others (supplemental type certificate holders and third-party suppliers) will provide corresponding performance data that air carriers will be able to use during flight planning and decision-making. As a result, Safety Recommendation A-07-63 remains classified "Open—Acceptable Response" pending the implementation of the RCAM and its use in reporting runway surface conditions.

The implementation and use of the RCAM does not address the requested actions in Safety Recommendation A-07-64, which asked the FAA to do the following:

> Demonstrate the technical and operational feasibility of outfitting transport-category airplanes with equipment and procedures required to routinely calculate, record, and convey the airplane braking ability required and/or available to slow or stop the airplane during the landing roll. If feasible, require operators of transport-category airplanes to incorporate use of such equipment and related procedures into their operations.

The FAA has sponsored the development and evaluation of these systems over the past several years and provided a briefing to the NTSB on September 6, 2016, about the status of this work. The FAA indicated that this work included research efforts through contracts awarded by

[105] Table 4 provides details about each airplane's make and model and time that each airplane landed in reference to the accident landing.

its William J. Hughes Technical Center in Atlantic City, New Jersey; work conducted at its technical center; and agreements with private companies.

The research and development of the recommended systems continues, as shown by the activities of the CAST and the private organizations that have briefed the NTSB about the status of their related projects. For example, the NTSB has learned that one system under development is being designed to calculate the friction coefficient developed by an airplane during a landing and quickly transmit the results of the calculation and other measurements to an on-ground network for processing and distribution to the company's customers.[106] Therefore, the NTSB recommends that the FAA continue to work with industry to develop the technology to outfit transport-category airplanes with equipment and procedures to routinely calculate, record, and convey the airplane braking ability required and/or available to slow or stop the airplane during the landing roll.

Safety Recommendation A-07-64 was issued in part to ensure that the objective calculations of airplane braking ability generated from such equipment (and the related operational procedures) would be conveyed to the flight crews of arriving aircraft and other stakeholders in the National Airspace System (NAS), including airport operators and ATC personnel. Although the FAA has been evaluating and sponsoring the development of these systems, the NTSB remains concerned that, when these systems are fully validated and become commercially available, the information that they provide might be available only to the individual operators that voluntarily equip their fleets with such systems and the organizations that subscribe to the service providing the data instead of all others with a safety need for this information.

The NTSB believes that the safety-related information provided by these systems should be in a form that will facilitate timely reporting of the results to all arriving aircraft, among other relevant NAS stakeholders. As a result, the FAA will need to develop policies and procedures for disseminating the information from these systems. Therefore, the NTSB also recommends that, if the systems described in Safety Recommendation A-16-23 are shown to be technically and operationally feasible, the FAA work with operators and the system manufacturers to develop procedures that ensure that airplane-based braking ability results can be readily conveyed to, and easily interpreted by, arriving flight crews, airport operators, ATC personnel, and others with a safety need for this information.

The FAA has consistently indicated that it would encourage, but not mandate, the use of airplane-based systems that determine runway surface conditions. However, given the success of CAST in effecting widespread voluntary introduction of safety improvements (including FAA-approved voluntary safety programs such as FOQA and the Aviation Safety Action Program), many operators might voluntarily equip their fleets with these systems if they are shown to be feasible, even without regulatory action by the FAA. Thus, if the FAA takes the

[106] The NTSB understands that the FAA is still in the process of vetting and validating the calculations performed by this system and that work remains to determine how the calculated results are to be used by the company's customers for operational decisions.

actions necessary to satisfy Safety Recommendations A-16-23 and -24, the intent of Safety Recommendation A-07-64 will also be satisfied without the FAA mandating the requested action. As a result, Safety Recommendation A-07-64 is reclassified "Closed—Acceptable Action/Superseded."

## 2.4 Evacuation Issues

### 2.4.1 Evacuation Procedures

After unexpectedly departing the paved runway surface, the airplane came to rest at a non-normal attitude with its nose over water and left wing damaged. The accident sequence also damaged the electrical systems, which resulted in the loss of the interphone and public address system as a means for communication. As a result, the two flight attendants in the aft cabin left their assigned locations and walked to the forward cabin (to obtain information from the flight crew and the lead flight attendant) while instructing passengers to stay seated and stay calm. The lead flight attendant left her assigned location to check on a passenger in the mid-cabin. However, the flight attendants were expected to stay near their assigned exit and remain in a state of readiness for an evacuation, which included assessing their exits to determine their status.[107]

Once the captain exited the flight deck, he met the flight attendants in the forward galley. The captain asked about the status of the forward and 2L door exits. The captain also asked whether the tailcone exit would also be available for an evacuation, and the flight attendant who had been seated at the tailcone replied "I don't know." Recognizing that no one was monitoring the aft cabin, one of the aft flight attendants walked back to her assigned position. A passenger stopped the flight attendant to tell her that a first responder was motioning to open the right overwing exits, to which she replied, "no, we need to wait until our captain instructs us to evacuate."

A first responder told the first officer, while he was in the cockpit, that everyone should evacuate the airplane via the right overwing exits due to fuel leaking from the left wing. The first officer relayed this information to the captain, and the captain told the flight attendants that they should prepare for an evacuation using the right overwing exits. Soon afterward, the captain retrieved the forward megaphone, gave it to the lead flight attendant, and told her to begin an evacuation. Videos taken by a passenger in the aft cabin showed that flight attendants first indicated their intent to evacuate the airplane about 6 minutes after the airplane came to a stop, when the lead flight attendant instructed passengers that they would need to evacuate "very calmly, slowly, and single file." The passengers were also instructed to remain seated and leave their carry-on baggage but were then told that they could stand to retrieve "coats, hats, scarves,

[107] During a postaccident interview with the FAA cabin safety inspector who had oversight responsibility for Delta's flight attendant program, the inspector stated her expectation that flight attendants would remain at their assigned locations during emergencies.

[and] gloves" because "it's cold outside." Many passengers were then seen on the videos standing and moving around in the aisle.

The videos also showed the flight attendants' confusion about the timing of the evacuation. For example, one of the aft flight attendants asked the lead flight attendant, "are we doing this now?" to which she replied, "I don't know." The evacuation began about 6 minutes after passengers were first told of the need to evacuate (and about 12 minutes after the airplane came to a stop), and it took more than 17 minutes after the airplane came to a stop for all of the passengers to evacuate.

One reason for the flight attendants' confusion during the evacuation was the flight crew's lack of assertiveness, timely decision-making, and communication. Delta's *Flight Crew Training Manual* stated that, for unplanned evacuations, the captain needed "to analyze the situation carefully before initiating an evacuation order" and then take "quick actions in a calm and methodical manner" after an evacuation decision to improve the chances of a successful evacuation. Postaccident interviews with the flight attendants indicated that the captain did not convey a sense of urgency to evacuate the cabin, and the first officer confirmed, during a postaccident interview, that ARFF personnel requested the evacuation. Also, although the flight crew learned about the fuel leak from a first responder before the evacuation, the flight crew did not share that information with the flight attendants, who learned about the fuel leak from a first responder after the evacuation had already begun.

Another reason for the flight attendants' confusion during the evacuation was the inadequate cabin crew procedures and training for a non-normal or an emergency situation after landing. Delta's flight attendant manual stated that, if the flight crew instructed the passengers to remain seated after an emergency or unusual situation, the flight attendants were to await evacuation instructions from the flight crew (unless the conditions were life threatening, in which case the flight attendants had the authority to initiate an evacuation).[108] However, after the accident, the flight attendants could not receive any instructions from the flight crew because of the inoperative communications systems. Delta's flight attendant manual had no procedures for communicating during an emergency situation without an operative public address system and interphone, and the flight attendant training curriculum did not address such a situation.

The megaphones located in overhead bins in both the forward and aft cabin would have provided an alternate means of communication among the flight attendants if they had retrieved and used them before leaving their assigned exits. Another potential means of communications would have been for one of the aft flight attendants to relay information between the two ends of the cabin while the other aft flight attendant and the lead flight attendant remained in their assigned parts of the cabin.

In addition, Delta did not have guidance instructing flight attendants to remain at their assigned exits during a situation similar to that encountered after this accident. Even though the

[108] The flight attendant manual also instructed flight attendants not to evacuate the airplane "if there was no immediate danger after 30 seconds."

airplane had come to a stop, the airplane was not at a normal gate location or a normal attitude, and the possibility for an emergency evacuation remained. If the flight crew had commanded an evacuation or a life-threatening situation had occurred while the flight attendants were away from their assigned exits (such as the leaking fuel igniting outside the airplane), passengers blocking the aisle could have prevented the flight attendants from reaching and opening their assigned emergency exits. Although 14 *CFR* 121.391(d) required flight attendants to "be located as near as practicable to required floor level exits" during landing and "be uniformly distributed throughout the airplane in order to provide the most effective egress of passengers in event of an emergency evacuation," the NTSB could not find any specific FAA guidance that emphasized the need for flight attendants to remain at their assigned exits during a non-normal situation after landing.

Given that the airplane was stopped off the runway at an unusual attitude and with damage, the captain's decision to evacuate the airplane should have come earlier in the sequence of events and before the request from ARFF personnel to evacuate. As a result, a significant amount of time had elapsed before the captain commanded the evacuation, which contributed to the flight attendants' confusion about the timing of the evacuation. However, once the captain commanded the evacuation, the flight attendants were expected to immediately begin the evacuation and follow their procedures for evacuating the cabin as expeditiously as possible, so instructing the passengers to retrieve their "coats, hats, scarves, [and] gloves" and go to the exits "very calmly, slowly, and single file" was inconsistent with those procedures and resulted in a 6-minute delay before the first passengers exited the airplane.[109] Also, passengers who retrieved their coats (per the flight attendants' instructions) blocked the aisle, which further impeded a rapid egress from the airplane. The NTSB concludes that the flight and cabin crews did not conduct a timely or an effective evacuation because of the flight crew's lack of assertiveness, prompt decision-making, and communication and the flight attendants' failure to follow standard procedures once the captain commanded the evacuation.

The NTSB also concludes that the flight attendants were not adequately trained for an emergency or unusual event that involved a loss of communications after landing and that the flight attendants' decision to leave their assigned exits unattended after the airplane came to a stop resulted in reduced readiness for an evacuation. Therefore, the NTSB recommends that the FAA require Part 121 operators to provide (1) guidance that instructs flight attendants to remain at their assigned exits and actively monitor exit availability in all non-normal situations in case an evacuation is necessary and (2) flight attendant training programs that include scenarios requiring crew coordination regarding active monitoring of exit availability and evacuating after a significant event that involves a loss of communications.

[109] As stated in section 1.7.1, Delta's flight attendant manual stated that, once an evacuation order or decision was made, the flight attendants were supposed to command "Come this way! Leave everything!" to evacuate passengers.

### 2.4.2 Evacuation Communication, Coordination, and Decision-making

This accident demonstrated problems with evacuation communication, coordination, and decision-making. The NTSB has investigated other accidents in which similar problems occurred and made related safety recommendations. For example, on December 20, 1995, a Tower Air 747 veered off the left side of the runway at JFK after an attempted takeoff. After the airplane stopped, the purser and three flight attendants attempted to use the interphone without success and did not use megaphones as an alternative. Also, the purser was unaware that his announcements over the public address system were only audible in the forward cabin, so passengers and flight attendants in the aft cabin did not receive any information. A deadheading flight attendant went to the forward cabin to find out the plans for the evacuation, but he did not return to the aft cabin to share information with the flight attendants there. As a result, the NTSB issued Safety Recommendation A-96-157, which asked the FAA to ensure that air carriers had adequate procedures for flight attendant communications, including those for coordinating emergency commands to passengers, transmitting information to flight crews and other flight attendants, and handling postaccident situations in which normal communications systems have been disrupted (NTSB 1996).[110]

The difficulties that can result when a normal means of communication becomes unavailable were also demonstrated in the July 6, 1996, accident involving a Delta MD-88 in Pensacola, Florida. An uncontained engine failure occurred during the initial part of the takeoff roll. The aft flight attendants attempted to call the flight crewmembers to inform them that they (the flight attendants) were initiating an evacuation as a result of structural damage, passenger injuries, and an engine fire, but the interphone was not functioning. As a result, the flight attendants began to evacuate passengers in the back of the airplane while the flight crew, unaware of the situation in the back of the airplane, instructed passengers to remain seated (NTSB 1998).

The NTSB had previously discussed the importance of good communication and coordination among crewmembers in its June 1992 special investigation report on flight attendant training and issued Safety Recommendation A-92-77, which asked the FAA to require that flight attendants receive CRM (including group exercises) to improve crewmember coordination and communication. The FAA responded by revising AC 120-51B, "Crew Resource Management Training," to include this training for flight attendants. The NTSB also issued Safety Recommendation A-92-74, which asked the FAA to ensure that "all reasonable attempts" were made to conduct joint flight crew/flight attendant evacuation drills during recurrent training. In response, the FAA directed POIs to ensure that their assigned certificate holders were aware of the performance benefits that result when flight crews and flight attendants conduct emergency evacuation drills together (NTSB 1992).[111] However, the FAA did

[110] The NTSB classified Safety Recommendation A-96-157 "Closed—Acceptable Action" on February 23, 1998. The full recommendation response history for this and other safety recommendations referenced in this section can be found by searching the NTSB's safety recommendation database.

[111] On January 23, 1996, the NTSB classified Safety Recommendation A-92-74 "Closed—Unacceptable Action." On July 15, 1996, the NTSB classified Safety Recommendation A-92-77 "Closed—Acceptable Action."

not require air carriers to conduct joint exercises with flight attendants and flight crews. Such exercises could promote discussions about the responsibilities of both crews and coordination of the crews' duties.

The NTSB's June 2000 safety study on emergency evacuations of commercial airplanes found continuing communication and coordination problems among flight and cabin crewmembers during airplane evacuations. The NTSB stated that joint evacuation exercises for flight and cabin crews could be effective in resolving such problems and, as a result, issued Safety Recommendation A-00-85, which again asked the FAA to require air carriers to conduct periodic joint evacuation exercises involving flight and cabin crews (NTSB 2000). The FAA responded that most air carriers did not conduct joint emergency evacuation exercises and that the agency would not require such exercises.[112]

Regarding evacuation decision-making, the NTSB has investigated other accidents in which the decision to evacuate was delayed. For example, on May 10, 2005, a Northwest Airlines DC-9 struck a parked Northwest Airlines A319 during taxi at MSP.[113] The DC-9 rolled under the tail of the A319, spinning and pushing the airplane about 60 feet, and the DC-9 stopped with the trailing edge of the A319 right wing embedded under the roof of the DC-9 cockpit. The DC-9 crew began evacuating passengers about 2 minutes after the collision. However, despite the damage to the airplane, the A319 crew did not begin evacuating passengers until about 10 minutes after the collision.[114]

Breakdowns in communications, coordination, and decision-making can have serious consequences in situations necessitating an airplane evacuation, and FAA efforts to fully address these issues have so far been insufficient. A multidisciplinary effort that focuses on analyzing data involving airplane evacuations and identifying ways to improve flight and cabin crewmember performance could be an effective way to resolve recurring evacuation-related issues.

The NTSB concludes that this and other accidents demonstrate the need for improved decision-making and performance by flight and cabin crews when faced with an unplanned evacuation. Therefore, the NTSB recommends that the FAA develop best practices related to evacuation communication, coordination, and decision-making during emergencies through the establishment of an industry working group and then issue guidance for Part 121 air carriers to use to improve flight and cabin crew performance during evacuations.

In addition, as discussed in section 1.10.3.3, the NTSB issued Safety Recommendation A-09-27 in response to its findings from the American Airlines flight 1400

[112] On October 21, 2004, the NTSB classified Safety Recommendation A-00-85 "Closed—Unacceptable Action."

[113] For more information about this accident, see CHI05MA111A and CHI05MA111B.

[114] In addition, the NTSB is currently investigating two 2015 accidents with emergency evacuation issues. Preliminary findings indicate that both evacuations began while an engine was still operating. For more information about these accidents, see DCA15FA185 and DCA16FA013.

accident. The recommendation asked the FAA to update the guidance and training provided to flight and cabin crews regarding communication and coordination during emergency and unusual situations. On August 28, 2012, the FAA stated that a revision to AC 120-48, which was expected in 2013, would provide updated guidance regarding communications during emergency and unusual situations to reflect the latest industry knowledge based on lessons learned. However, as of September 1, 2016, the FAA had not issued the revised AC. Given the inadequate communication and coordination among the Delta flight 1086 flight and cabin crewmembers, the NTSB reiterates Safety Recommendation A-09-27 and reclassifies it "Open—Unacceptable Response."

## 2.5 Emergency Response Issues

### 2.5.1 Accident Notification and Emergency Response

The first individual to see the accident airplane after it departed the runway was the leader of LGA's snow removal red team, who informed the LGA snow coordinator that the airplane had hit a fence. The snow coordinator was unable to see the airplane from his vehicle's location at the time, but he began to respond. At 1104:00, the snow coordinator notified the local controller that runway 13 was closed and then proceeded onto the runway in his vehicle. Because the controller had not responded to the snow coordinator's notification, he repeated that the runway was closed. At 1104:16, the local controller asked the snow coordinator whether the runway was closed, and the snow coordinator confirmed that information. About 14 seconds later (and 33 seconds after the initial notification that the runway was closed), the controller instructed the flight crew of Delta flight 1999 (the next arriving airplane for runway 13) to go around.

On the basis of airport protocol and the letter of agreement with the ATC tower, the snow coordinator had likely assumed that the controller would have immediately closed the runway. However, this assumption led to a situation in which the snow coordinator's vehicle was on the runway for about 23 seconds while Delta flight 1999 was on final approach. At the time of the controller's go-around instruction, the flight 1999 airplane was only about 30 seconds from landing.

The controller did not expect an abrupt closure of the runway and had likely assumed that the closure was due to the winter weather. (The snow coordinator did not state that the accident was the reason for the closure.) However, the controller had just attempted to contact the accident airplane's flight crew six times without a response, so he might have reacted more quickly if he had integrated that information along with the runway closure information.

Airport operations personnel notified the airport operations manager via cell phone that an airplane had departed the paved runway surface, hit a fence, and was leaking fuel. At the time, the airport operations manager happened to be engaged in a face-to-face conversation with the ARFF deputy chief and relayed the phone call information to him. At 1104:35, the deputy chief called the ARFF crew chief to prepare ARFF crews for a response based on the phone call information. However, because the airplane's precise location was not provided as part of the initial cell phone call, the only information that the ARFF crews had regarding the accident location was that the airplane had hit a fence.

At 1104:38, a responding airport operations staff member notified the local controller about the accident. At 1104:48, another responding airport operations staff member told the controller, "you have an aircraft off [runway] 3-1 on the north vehicle service road. Please advise crash/rescue." However, the EANS—the primary method for communicating an emergency at LGA—was not immediately activated by ATC tower personnel. The snow coordinator arrived on scene and told the controller at 1105:55 that the airplane was "leaking fuel on the left side of his aircraft heavily…his wing is ruptured." Thirty seconds later (and about 3.5 minutes after the airplane came to a stop), ATC tower personnel activated the EANS, which reported "LaGuardia, Alert 3, all emergency vehicles respond. Alert 3, Delta 1086 MD-80, just east of runway 1-3, wing eruption, fuel is being leaked."[115]

The airport's ASDE-X showed ARFF vehicles leaving the fire station area about 1107 to respond to the accident. ARFF crews initially searched fenced areas at the approach end of runway 13 but did not locate the airplane there. Radio communications indicated that ARFF personnel were still unclear of the exact location and the severity of the accident as of 1110:12. ARFF personnel eventually saw the airplane on the embankment and arrived at the accident site about 1111:02, which was more than 8 minutes after the accident occurred.

The initial information that airport operations personnel provided about the nature, location, and severity of the accident was somewhat ambiguous, which likely caused confusion for the local controller, who could not see the accident site. However, the controller did not actively seek additional information about the situation or effectively use the information available to him. In addition, airport operations personnel clearly requested at 1104:48 that the controller notify ARFF personnel about the accident, but the EANS was not activated for another 1 minute 37 seconds. Thus, the NTSB concludes that ARFF personnel would likely have arrived at the accident scene sooner if they had received more timely and precise information about the accident and its location.

### 2.5.2 Passenger Manifests

The passenger count provided by the flight and cabin crews did not fully reflect the total number of passengers aboard the airplane. The first officer used the information in the final weight and balance report sent via ACARS to inform ATC tower personnel that 125 passengers were aboard the airplane. The lead flight attendant provided Port Authority personnel with the departure report, which also indicated that 125 passengers were aboard the airplane, and one of the flight attendants confirmed that passenger count to the LGA manager of airport operations. However, later in the day, LGA airport operations staff learned that 127 passengers were

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[115] A responding airport operations staff member who reported the accident to the controller used the term "3-4," which had previously been used to describe the highest level of airplane emergency at LGA. However, ATC tower personnel used the correct term "alert 3" in the EANS notification. Thus, the initial incorrect terminology did not appear to cause any confusion for ATC tower personnel.

actually aboard the airplane. Two lap-held children were noted in the body of the departure report (with an adult's name and seat location), but they were not included in the total passenger count. According to Delta, departure reports were generated from scanned passenger boarding passes, and lap-held children were not issued boarding passes.

The NTSB made a similar finding during its investigation of the December 29, 2010, incident involving American Airlines flight 2253, which overran the end of the runway after landing at Jackson Hole Airport, Jackson Hole, Wyoming. The passenger manifest indicated that four lap-held children were aboard the airplane, but they were not included in the manifest's total passenger count. As a result, the total passenger count provided to airport officials, ARFF crews, and the NTSB did not include the lap-held children (NTSB 2012).[116]

The NTSB has also investigated accidents in which lap-held children were not included in any part of a flight's passenger manifest. These accidents include the July 2, 1994, accident involving USAir flight 1016 in Charlotte, North Carolina, and the May 11, 1996, accident involving ValuJet Airlines flight 592, which crashed into the Everglades after takeoff from Miami International Airport, Miami, Florida (NTSB 1995, 1997).[117]

Title 14 *CFR* 121.693, "Load Manifest: All Certificate Holders," paragraph (e) required certificate holders to prepare a load manifest that included the names of passengers aboard a flight at the time of takeoff (unless the passenger names were maintained by a means other than a load manifest). The FAA's Air Carrier Operations Bulletin 8-91-2 stated that "the principal reason for this regulation is to facilitate the rapid and accurate determination of how many passengers are on board an aircraft and who they are in the event of an emergency situation." The bulletin also stated that air carriers should provide this information "to an appropriate airport and/or Government authority" in an accurate and timely manner. Further, the bulletin stated that the term "passenger" in the *Federal Aviation Regulations* meant any passenger regardless of age. Nevertheless, Delta's procedures for providing the total number of passengers aboard a flight resulted in an inaccurate initial passenger count after the accident.

The NTSB concludes that, even though the initial uncertainty regarding the total number of passengers aboard the accident flight, including lap-held children, did not lead to any adverse outcomes, such uncertainty could be detrimental under other accident circumstances, especially if search and rescue efforts are needed. Flight and cabin crewmembers involved in an accident or incident should be able to provide emergency responders with an accurate passenger count (including lap-held children) upon exiting the airplane and without contacting company personnel for further information. Therefore, the NTSB recommends that the FAA clarify guidance to all Part 121 air carriers to reinforce the importance of (1) having precise information

[116] More information about this incident is available in the Survival Factors Specialist's Factual Report in the incident docket.

[117] As a result of the ValuJet flight 592 accident, the NTSB issued Safety Recommendation A-97-77, which asked the FAA to "instruct principal operations inspectors to review their air carriers' procedures for manifesting passengers, including lap children, and ensure that those procedures result in a retrievable record of each passenger's name." The NTSB classified this recommendation "Closed—Acceptable Action" on July 23, 1999.

about the number of passengers aboard an airplane, including lap-held children, and (2) making this information immediately available to emergency responders after an accident to facilitate timely search and rescue operations.

## 2.6 Airport Issues

### 2.6.1 Runway Friction Measurement Policies

Many airports use CFME or decelerometers during winter conditions to assess the effectiveness of runway clearing operations.[118] LGA's *Airport Certification Manual* stated that the airport used CFME to conduct friction readings when conditions required trend analysis on a frozen or contaminated surface. Also, Port Authority's letter of agreement with the LGA ATC tower stated that airport operations staff could conduct friction assessments when conditions might result in degraded runway surface friction and that such assessments could be conducted using CFME. However, LGA's chief operations supervisor stated that the airport's two CFME vehicles were not used during snow removal operations and that the vehicles were only used to assess runway friction related to rubber removal.

LGA had not been using CFME during winter operations since a change in Port Authority policy that was effective in November 2011. The policy was based on information in a letter from the FAA's Office of Airport Safety and Standards, which responded to Port Authority's questions about the airport winter operations guidance in AC 150/5200-30C. The letter confirmed that the FAA did not require airports to conduct friction surveys in winter conditions but recognized that "operational [friction] testing under winter conditions can be a valuable tool to airport operators in providing information on changing runway conditions." This information was consistent with the FAA's guidance in AC 150/5200-30C, which stated that "some airport users still consider runway friction measurement values to be useful information for tracking the trend of changing runway conditions." The letter also confirmed that the FAA no longer recommended providing friction measurements (Mu values) to pilots but advised that providing friction measurement reports to other interested parties for the purpose of trend analysis was permitted.

The LGA manager of airport operations stated two other airports operated by Port Authority—JFK and EWR—had also not been using CFME during winter operations since the Port Authority friction testing policy became effective. He stated that the operations and certification managers from all three airports met about the friction testing policy and made the decision not to use CFME during winter operations. The managers agreed that the airports needed one consistent operational interpretation of the policy memorandum and believed that the decision not to use CFME during winter operations followed the FAA's guidance because Mu values were not being provided to pilots.

[118] Delta surveyed 143 airports in its special winter operations airport program and found that about 80% of the airports used either CFME or a decelerometer to assess runway friction during winter operations. LGA was not identified as a special winter operations airport for the 2014-2015 winter season.

LGA personnel could not fully explain why they were not using CFME during winter conditions to obtain useful trend information about changing runway conditions, and these personnel repeatedly maintained that the FAA did not require friction testing and that Mu values were unreliable because they could not be correlated to braking action.[119] Although LGA was using direct observations, along with in-pavement runway sensor information and pilot reports, to assess runway surfaces, CFME would be an additional objective data source that could provide airport operations staff with important information about changing runway conditions regardless of whether such data were shared with pilots or operators.

As previously stated, runway friction was sufficient at the time of the accident, so LGA's lack of use of CFME to monitor changes in runway friction before the accident was inconsequential. However, the NTSB concludes that, by not using its CFME during winter operations, LGA did not take advantage of a tool that would allow the airport to objectively assess the effectiveness of snow removal operations on contaminated runways. The FAA continues to promote friction measuring equipment as a valuable tool for detecting trends in runway conditions during winter operations, including after the treatment of runway surfaces. Therefore, the NTSB recommends that Port Authority, after consultation with the FAA, clarify its policies regarding CFME use during winter operations and ensure that this information is included in the *Airport Certification Manual* and Snow and Ice Control Plan for each airport operated by the Port Authority.

Despite conducting annual inspections at LGA in February 2014 and February 2015 (before the accident) and in November 2015 (after the accident), the FAA's ACSI was unaware that LGA was not using CFME during winter operations. He thought that the airport was using CFME for friction assessments because of the wording included in the *Airport Certification Manual* and letter of agreement with the ATC tower. Also, at the time of the accident, LGA's computer-based training course for winter operations indicated that the airport was using friction measuring equipment during winter weather conditions. Further, although FAA ACSIs conduct occasional surveillance inspections in addition to annual inspections, the ACSI for LGA indicated that he had not been directed to observe active airport winter operations during his more than 5 years with the FAA.

The NTSB is concerned that other ACSIs might not be fully aware of how an airport is assessing runway friction during winter weather operations. Therefore, the NTSB also recommends that, for airports certificated under Part 139, the FAA direct ACSIs to ensure, before or during the airports' next scheduled annual inspection, that policies and procedures for friction measurement during winter operations are accurately and adequately described in the airports' *Airport Certification Manual* and Snow and Ice Control Plan.

[119] LGA also did not use CFME to perform a friction assessment of runway 13 after the accident, even after Delta's request to do so. The NTSB notes that postaccident CFME runway friction assessments that are conducted immediately after an accident on a contaminated runway could provide valuable data to an investigation, especially if an airport operator had been using the equipment to analyze runway friction trends.

### 2.6.2 Runway Condition Reporting

The last NOTAM before the accident, issued at 0903, indicated that 1/4 inch of wet snow was on runway 13/31. The last airport snow measurement before the accident (at 1051) showed that 0.4 inch of snow had accumulated during the last hour. On the basis of this snow accumulation and the time between the last runway clearing and the accident (27 minutes), the NTSB estimated that the runway was contaminated with about 1/4 inch of snow at the time that the accident airplane touched down. Although this snow amount was the same as that in the 0903 NOTAM, the NTSB is concerned that the NOTAM was 2 hours old at the time of the accident and had not been updated after the snow clearing operations.

AC 150/5200-30C, which was current at the time of the accident, stated that NOTAMs describing the runway surface conditions must be "timely" because those conditions can change quickly as a result of winter weather conditions or the actions to mitigate those conditions. The AC also stated that runway condition reports needed to be updated any time a "change to the runway surface condition" occurred. Among other changes that would necessitate updated reports were weather events, chemical or sand applications, and plowing or sweeping operations.

LGA's chief operations supervisor stated that airport operations personnel did not routinely issue updated field condition reports after each snow clearing event. LGA's aeronautical operations manager indicated that, as long as the snow removal teams could maintain the runway condition described in the most recent NOTAM, the NOTAM would remain in effect. The FAA ACSI for LGA also believed that a new NOTAM would not need to be issued under those circumstances. However, these postaccident statements seemed to contradict the FAA guidance's in AC 150/5200-30C, which stated that airplane operations on runways should not be allowed after chemical or sand applications and plowing or sweeping operations until a new runway condition report was published to indicate the latest runway surface condition.

The NTSB notes that the guidance in AC 150/5200-30C did not specifically describe what constituted a "timely" NOTAM and what types of "change to the runway surface condition" airport operations personnel needed to report. In addition, version D of the AC, which was issued in July 2016, does not provide clarification about these terms. If these terms were clarified, airport operations personnel could issue more effective NOTAMs, and flight crews could have more updated information regarding runway surface conditions. The NTSB concludes that the FAA's airport winter operations safety guidance is not sufficiently clear about the timing and need for updated runway condition reports, which could result in flight crew uncertainty about possible runway contamination. Therefore, the NTSB recommends that the FAA revise AC 150/5200-30D to provide more precise guidance regarding (1) the need to issue NOTAMs in a timely manner and (2) the specific changes to runway surface conditions that would prompt the issuance of updated NOTAMs.

During a December 2015 meeting between LGA airport operations staff and the chief pilots for air carriers that operate at the airport, LGA staff indicated that it would update NOTAMs during winter operations each hour, regardless of whether runway conditions changed, and as necessary between hourly reports. The NTSB believes that this approach can help ensure that pilots receive timely and accurate information about the runway conditions at LGA.

## 2.7 Delta Air Lines Postaccident Actions

According to Delta, as of June 7, 2016, the company had taken the following actions in response to the safety issues involved in this accident:

**MD-88 reverse thrust usage**

- On March 11, 2016, the normal reverse thrust for dry runways was adjusted to 1.3 EPR.
- As of May 18, 2016, MD-88 landing distances were calculated using idle reverse thrust.
  - For dry runways, flight crews were to use 1.3 EPR.
  - For runways that are not dry, flight crews were to initially select idle reverse thrust. After reverse thrust symmetry was verified and the airplane was aligned with the runway track, crews could "methodically and gradually" increase reverse thrust to no more than 1.3 EPR if required to reduce stopping distance.
- Delta's technical operations department was implementing a new maintenance procedure to decrease asymmetric spool-up when reverse thrust is selected.
- A safety management system safety risk assessment was initiated to review reverse thrust usage on the MD-88.
- Company fleet bulletins and articles highlighted the use of reverse thrust on the MD-88.

**Operational landing distance data**

- On May 4, 2015, Delta activated the ACARS landing performance request tool for flight crew use. (Delta had begun testing the tool 2 months before the accident.) According to Delta, the landing performance request tool calculates runway-specific operational landing distance data and reduces the need for crews to reference the *Operational Data Manual* and interpolate and manually apply corrections.
- Delta aligned its braking action table with the TALPA ARC recommendations.

**Operations on contaminated runways**

- MD-88 pilots received a flight safety electronic bulletin discussing contaminated runway awareness.
- Delta was sponsoring two demonstration studies of aircraft-based technology for conducting runway friction assessments on contaminated runways.

**Special winter operations airport program**

- Delta identified LGA as a special winter operations airport for the 2015-2016 winter season. (As previously stated, LGA was not identified as a special winter operations airport for the 2014-2015 winter season, during which time the accident occurred.)

- A Delta senior vice president sent a letter to Port Authority "urging" the adoption of a more robust friction assessment program.
- Delta made "repeated requests" to LGA to issue hourly field condition reports, and LGA agreed (as discussed in section 2.6.2).
- In December 2015, Delta's flight safety department initiated a review of the special winter operations airport program to assess its effectiveness. The group conducting the review determined that the program was effective in identifying and mitigating potential runway excursion risks during winter operations. The group identified changes to enhance the program's assessment of airports and the methods to mitigate identified hazards. Also, the group recommended several modifications to address the upcoming changes resulting from the TALPA program.

# 3. Conclusions

## 3.1 Findings

1. The flight crew was properly certificated and qualified in accordance with federal regulations and company requirements. Flight crew fatigue was likely not a factor in this accident. The airplane was properly certificated, equipped, and maintained in accordance with federal regulations. No evidence indicated any preimpact structural, engine, or system failures.

2. The flight crewmembers' uncertainty about the runway conditions at LaGuardia Airport led to some situational stress for the captain.

3. The flight crew was well prepared for the approach and established landing requirements that were consistent with company policies.

4. Even though the flight crewmembers' observations of snow on the runway were inconsistent with the expectations that they formed based on the field condition information that they received, their decision to continue the approach was not inappropriate because the landing criteria had been met.

5. Although the runway was contaminated with snow, runway friction when the accident airplane landed was sufficient for stopping on the available runway length.

6. The circumstances associated with the landing, including the snowier-than-expected runway, short runway length, and body of water off the departure end of the runway, likely exacerbated the captain's situational stress and prompted him to make an aggressive input on the thrust reversers.

7. The captain was unable to maintain directional control of the airplane due to rudder blanking, which resulted from his application of excessive reverse thrust.

8. Even though the first officer promptly identified rudder blanking as a concern and the captain stowed the thrust reversers in response, the airplane's departure from the left side of the runway could not be avoided because directional control was regained too late to be effective.

9. A solution to reliably limit reverse thrust engine pressure ratio values could benefit all pilots of MD-80 series airplanes.

10. A callout when reverse thrust exceeds 1.3 engine pressure ratio during landings on contaminated runways could help avoid rudder blanking and a subsequent loss of directional control.

11. An automated alert could help minimize the possibility of reverse thrust engine pressure ratio exceedances during the landing rollout.

12. This accident demonstrates the continuing need for objective, real-time, airplane-derived data about runway braking ability for flight crews preparing to land with runway surface conditions that are worse than bare and dry.

13. The flight and cabin crews did not conduct a timely or an effective evacuation because of the flight crew's lack of assertiveness, prompt decision-making, and communication and the flight attendants' failure to follow standard procedures once the captain commanded the evacuation.

14. The flight attendants were not adequately trained for an emergency or unusual event that involved a loss of communications after landing, and the flight attendants' decision to leave their assigned exits unattended after the airplane came to a stop resulted in reduced readiness for an evacuation.

15. This and other accidents demonstrate the need for improved decision-making and performance by flight and cabin crews when faced with an unplanned evacuation.

16. Aircraft rescue and firefighting personnel would likely have arrived at the accident scene sooner if they had received more timely and precise information about the accident and its location.

17. Even though the initial uncertainty regarding the total number of passengers aboard the accident flight, including lap-held children, did not lead to any adverse outcomes, such uncertainty could be detrimental under other accident circumstances, especially if search and rescue efforts are needed.

18. By not using its continuous friction measuring equipment during winter operations, LaGuardia Airport did not take advantage of a tool that would allow the airport to objectively assess the effectiveness of snow removal operations on contaminated runways.

19. The Federal Aviation Administration's airport winter operations safety guidance is not sufficiently clear about the timing and need for updated runway condition reports, which could result in flight crew uncertainty about possible runway contamination.

## 3.2 Probable Cause

The National Transportation Safety Board determines that the probable cause of this accident was the captain's inability to maintain directional control of the airplane due to his application of excessive reverse thrust, which degraded the effectiveness of the rudder in controlling the airplane's heading. Contributing to the accident were the captain's (1) situational stress resulting from his concern about stopping performance and (2) attentional limitations due to the high workload during the landing, which prevented him from immediately recognizing the use of excessive reverse thrust.

# 4. Recommendations

## 4.1 New Recommendations

As a result of this investigation, the National Transportation Safety Board makes the following new safety recommendations:

**To the Federal Aviation Administration:**

> Collaborate with Boeing and US operators of MD-80 series airplanes to (1) conduct a study to examine reverse thrust engine pressure ratio (EPR)-related operational data, procedures, and training and (2) identify industry-wide best practices that have been shown to be effective in reliably preventing EPR exceedances to mitigate the risks associated with rudder blanking. (A-16-20)
>
> Encourage US operators of MD-80 series airplanes to (1) implement the best practices identified in Safety Recommendation A-16-20 and (2) participate in an industry-wide monitoring program to verify the continued effectiveness of those solutions over time. (A-16-21)
>
> Require operators of MD-80 series airplanes to revise operational procedures to include a callout when reverse thrust power exceeds 1.3 engine pressure ratio during landings on a contaminated runway. (A-16-22)
>
> Continue to work with industry to develop the technology to outfit transport-category airplanes with equipment and procedures to routinely calculate, record, and convey the airplane braking ability required and/or available to slow or stop the airplane during the landing roll. (A-16-23)
>
> If the systems described in Safety Recommendation A-16-23 are shown to be technically and operationally feasible, work with operators and the system manufacturers to develop procedures that ensure that airplane-based braking ability results can be readily conveyed to, and easily interpreted by, arriving flight crews, airport operators, air traffic control personnel, and others with a safety need for this information. (A-16-24)
>
> Require 14 *Code of Federal Regulations* Part 121 operators to provide (1) guidance that instructs flight attendants to remain at their assigned exits and actively monitor exit availability in all non-normal situations in case an evacuation is necessary and (2) flight attendant training programs that include scenarios requiring crew coordination regarding active monitoring of exit availability and evacuating after a significant event that involves a loss of communications. (A-16-25)
>
> Develop best practices related to evacuation communication, coordination, and decision-making during emergencies through the establishment of an industry

working group and then issue guidance for 14 *Code of Federal Regulations* Part 121 air carriers to use to improve flight and cabin crew performance during evacuations. (A-16-26)

Clarify guidance to all 14 *Code of Federal Regulations* Part 121 air carriers to reinforce the importance of (1) having precise information about the number of passengers aboard an airplane, including lap-held children, and (2) making this information immediately available to emergency responders after an accident to facilitate timely search and rescue operations. (A-16-27)

For airports certificated under 14 *Code of Federal Regulations* Part 139, direct airport certification safety inspectors to ensure, before or during the airports' next scheduled annual inspection, that policies and procedures for friction measurement during winter operations are accurately and adequately described in the airports' *Airport Certification Manual* and Snow and Ice Control Plan. (A-16-28)

Revise Advisory Circular 150/5200-30D, "Airport Field Condition Assessments and Winter Operations Safety," to provide more precise guidance regarding (1) the need to issue notices to airmen (NOTAM) in a timely manner and (2) the specific changes to runway surface conditions that would prompt the issuance of updated NOTAMs. (A-16-29)

**To Boeing:**

Collaborate with the Federal Aviation Administration and US operators of MD-80 series airplanes to (1) conduct a study to examine reverse thrust engine pressure ratio (EPR)-related operational data, procedures, and training and (2) identify industry-wide best practices that have been shown to be effective in reliably preventing EPR exceedances to mitigate the risks associated with rudder blanking (A-16-30)

Explore the possibility of incorporating an alert in MD-80 series airplanes to aid pilots in preventing engine pressure ratio exceedances. (A-16-31)

**To US operators of MD-80 series airplanes:**

Collaborate with the Federal Aviation Administration and Boeing to (1) conduct a study to examine reverse thrust engine pressure ratio (EPR)-related operational data, procedures, and training and (2) identify industry-wide best practices that have been shown to be effective in reliably preventing EPR exceedances to mitigate the risks associated with rudder blanking. (A-16-32)

**To the Port Authority of New York and New Jersey:**

After consultation with the Federal Aviation Administration, clarify your policies regarding continuous friction measuring equipment use during winter operations and ensure that this information is included in the *Airport Certification Manual* and Snow and Ice Control Plan for each airport operated by the Port Authority. (A-16-33)

## 4.2 Previously Issued Recommendation Reiterated in This Report

The National Transportation Safety Board reiterates the following recommendation to the Federal Aviation Administration:

> Revise Advisory Circular 120-48, “Communication and Coordination Between Flight Crewmembers and Flight Attendants,” to update guidance and training provided to flight and cabin crews regarding communications during emergency and unusual situations to reflect current industry knowledge based on research and lessons learned from relevant accidents and incidents over the last 20 years. (A-09-27)

## 4.3 Previously Issued Recommendations Classified in This Report

Safety Recommendation A-07-63 is classified “Open—Acceptable Response” in section 2.3 of this report.

Safety Recommendation A-07-64 is reclassified “Closed—Acceptable Action/Superseded” in section 2.3 of this report. This recommendation is superseded by Safety Recommendations A-16-23 and -24.

Safety Recommendation A-09-27 is reclassified “Open—Unacceptable Response” in section 2.4.2 of this report.

## BY THE NATIONAL TRANSPORTATION SAFETY BOARD

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Member

**Adopted: September 13, 2016**

# Board Member Statement

**Member Robert L. Sumwalt filed the following concurring statement on September 20, 2016.**

This flightcrew was aware of the challenges they faced for this landing at New York's LaGuardia Airport. The captain took the precaution of deliberately arranging the flying so that he would fly this leg instead of having the first officer fly it. The crew briefed the approach very thoroughly. They carefully conducted landing distance assessments, and considered alternatives, including discussing fuel requirements to their alternate airport. On landing, the captain planted the airplane at the 600-foot point instead of waiting for the 1,000-foot marker that is usually targeted on landings. And, presumably because of his concern for stopping on this relatively short, snow-covered runway, he initiated reverse thrust promptly and aggressively. Unfortunately, his reverse thrust usage was excessive and because of the rudder blanking characteristics of the MD-80 series[1], the rudder effectiveness was diminished and directional control of the aircraft lost.

As a former airline pilot for over 20 years, I'm confident saying that having to limit reverse thrust on a relatively short, slippery runway is counter-intuitive: When you need it the most, you have to use it the least. Nevertheless, "rudder blanking" is a known phenomenon of the MD-80 series aircraft, and was highlighted in the NTSB's investigation of an MD-80 accident at Little Rock, Arkansas, in 1999.[2] In that accident, the aircraft touched down on a wet runway with a strong crosswind. The NTSB cited "use of reverse thrust greater than 1.3 engine pressure ratio after landing" as a contributing factor in the accident (NTSB, 2001, p. 170). Furthermore, NTSB issued a recommendation to FAA to "issue a flight standards information bulletin that requires the use of 1.3 engine pressure ratio as the maximum reverse thrust power for MD-80 series airplanes under wet or slippery runway conditions, except in an emergency in which directional control can be sacrificed for decreased stopping distance" (NTSB, 2001, p. 171).[3] NTSB also recommended FAA "review and determine that [MD-80] operators' flight manuals and training programs contain information on the decrease in rudder effectiveness when reverse thrust power in excess of 1.3 engine pressure ratio is applied" (NTSB, 2001, p. 171).[4]

[1] As referenced in the report, the MD-80 series incorporates the accident aircraft, which was designated as an MD-88. This statement refers to all in the MD-80 series as simply MD-80s and does not distinguish between MD-83, MD-88, and others in that series.

[2] NTSB. (2001). *Aircraft accident report: Runway Overrun During Landing, American Airlines Flight 1420, McDonnell Douglas MD-82, N215AA, Little Rock, Arkansas, June 1, 1999.* (NTSB Report No. NTSB/AAR-01/02). Washington, DC.

[3] Safety Recommendation A-01-051 was classified "Closed—Acceptable Action" on May 6, 2003.

[4] Safety Recommendation A-01-052 was classified "Closed—Acceptable Action" on May 6, 2003.

While there may have been "awareness" of rudder blanking and how it could diminish directional control, this awareness apparently didn't transfer into applied knowledge for the captain of Delta 1086 when he needed it most.

Further, NTSB's investigation found that other Delta pilots were not applying this awareness into practical knowledge, either. As I stated in the Board Meeting, I believe Delta Air Lines was not placing enough emphasis on proper use of reverse thrust. This concurring statement discusses the basis for that conclusion.

**Excessive EPR on other flights.** NTSB review of 80 Delta MD-80 landings found that of those on dry runways, 44 percent exceeded 1.6 EPR (the recommended maximum EPR on dry runways). Furthermore, of the 14 reviewed Delta MD-80 landings on runways where precipitation was present, all exceeded 1.3 EPR (the max recommended EPR on wet runways) and half exceeded 1.6 in at least one engine.

If one pilot repeatedly made the same error of over-application of reverse thrust, it would be easy to dismiss it as simply an outlier. Instead, the above data, which presumably consists of many landings by several different pilots, strongly indicates the issue is more widespread than simply a "one-off" problem.

**No requirement for approach briefing of EPR target.** In November 2002, Boeing issued a *Flight Operations Bulletin* pertaining to reverse thrust control on the MD-80 series.[5] In discussing directional control issues associated rudder blanking, the bulletin noted: "Approach briefings provide the opportunity for crews to anticipate the conditions that are likely to be encountered upon landing, and reverse thrust EPR targets may be identified as this time." Despite this recommendation from Boeing, and despite loss of directional control resulting from excessive EPR being a factor in the previously referenced MD-80 accident, Delta did not require this to be discussed in approach briefings.

A tenet of Threat and Error Management is to identify and discuss threats[6] ahead of time. Doing so draws attention to those particular threats and ensures that all crewmembers have a shared mental model of how they will deal with them. In the case of Delta 1086, as evidenced by his quick calls to "come out of reverse," the first officer was apparently well prepared for possible directional control issues due to excessive reverse thrust. However, it is likely that under

[5] Operational Factors Group Chairman's Factual Report, Attachment 21. *Boeing Flight Operations Bulletin MD-80-02-03*.

[6] FAA Advisory AC 120-90, *Line Operations Safety Audit*, states: "A threat is defined as an event or error that occurs outside the influence of the flightcrew (i.e., it was not caused by the crew), increases the operational complexity of a flight, and requires crew attention and management if safety margins are to be maintained. There are threats from the environment—adverse weather, airport conditions, terrain, traffic, and air traffic control (ATC)—and threats emanating from within the airline—aircraft malfunctions and master equipment list (MEL) items, problems, interruptions, or errors from dispatch, cabin, ground, maintenance, and the ramp. The crew, for example, may anticipate threats by briefing a thunderstorm in advance; or they may be unexpected, occurring suddenly and without warning such as in flight aircraft malfunctions. Some threats are easily resolved and quickly dismissed from the crew's workload, while other threats require greater attention and management."

the stress of the situation, use of excessive thrust was not at the forefront of the captain's mind. Had Delta required, and had the crew conducted, an approach briefing that specifically addressed proper reverse thrust usage and the associated possibility of directional control issues, it is possible the captain would have been more prepared to properly use reverse thrust.

**Not fully appreciating rudder blanking in Cancun event.** In 2012, a Delta MD-88 was involved in a runway excursion at Cancun, Mexico. While landing in heavy rain, a 10-knot crosswind, and on an un-grooved runway, the aircraft veered off the right side of the runway. EPR values were 2.0 on the right engine and 1.61 on the left engine, which were clearly above the 1.3 limit recommended by Boeing for such runway conditions. To Delta's credit, they developed and implemented Special Purpose Operational Training (SPOT) to ensure crews were properly trained to deal with landing on slick runways with crosswinds. However, when interviewed by NTSB, Delta's MD88 Chief Line Check Pilot and Delta's MD88 Fleet Captain each seemed to place more belief on the Cancun event being a hydroplaning-related event rather than one related to rudder blanking.[7] Despite the Cancun investigation revealing that excessive EPR was used, the Chief Line Check Pilot indicated he was unaware of the amount of EPR used in that event (*Interview Summaries*, at p. 32). Furthermore, the Fleet Captain told investigators he did not know if rudder blanking was an issue in the Cancun event (*Interview Summaries*, at p. 37). I believe because the implications of rudder blanking were not fully appreciated in this event, Delta missed a valuable opportunity to ensure it thoroughly addressed rudder blanking in the SPOT that was added because of the Cancun event.

**Understated Delta manuals and training guidance.** In 1996, Boeing issued *Boeing All Operators Letter AOL-9-058* [8], which addressed MD-80 handling characteristics when landing on wet or slippery runways. That letter to all MD-80 operators was prompted by an MD-80 that departed the runway during a heavy thunderstorm. The letter explained rudder blanking and how directional control can be compromised as a result of lack of rudder effectiveness. "While this may not be as relevant on a dry runway, rudder effectiveness is of extreme importance when surface friction is low," Boeing stated. "To further reduce the possibility of runway excursions during heavy weather operations, Douglas [Boeing] will revise its recommended procedures to limit reverse thrust to 1.3 EPR when landing on wet or slippery runways. Limiting reverse thrust to 1.3 EPR during heavy weather landings will avoid operations in the regime where reverse thrust decreases rudder effectivity." The letter also stated: "Additionally, Douglas [Boeing] recommends the following procedures be observed… When operating on wet or slippery runways…. Apply reverse thrust to idle reverse thrust detent. After reverse thrust is verified, gradually increase reverse thrust as required to no more than 1.3 EPR."

[7] Operational Factors Group Chairman's Factual Report, Attachment 1. *Interview Summaries.*

[8] Operational Factors Group Chairman's Factual Report, Attachment 19. *Boeing All Operators Letter AOL-9-058.*

Subsequently, in November 2002, Boeing issued a *Flight Operations Bulletin* pertaining to reverse thrust EPR control, cautioning that "1.3 engine pressure ratio (EPR) should be used as the maximum reverse thrust power under wet or slippery runway conditions."[9]

In May 2014, the Boeing *Flight Crew Operations Manual* (FCOM), Volume II, was revised with the following: "Caution: On wet, slippery or contaminated runways, stopping distance is based on maximum anti-skid braking, with application of no greater than 1.3 EPR reverse thrust."[10]

Whereas the above-cited Boeing guidance expressed 1.3 as the *maximum* EPR for wet, slippery, or contaminated runways, Delta's guidance only referred to 1.3 as a *target* value. Although a subtle distinction, pilots are taught to target certain parameters, such as a touchdown point on the runway. Sometimes that target is met and sometimes it isn't, but in each case, the pilot aims for that target. A maximum value, on the other hand, is one pilots know not to exceed.

Delta's guidance for the above-referenced SPOT stated: "Remember, applying reverse thrust above 1.3 EPR will potentially blank rudder effectiveness and degrade directional control." I believe that Delta's choice of such wording may have understated the hazard of using more than 1.3 EPR on wet, slippery, or contaminated runways. Applying reverse thrust above 1.3 EPR does not *potentially* blank rudder effectiveness, as stated by Delta. Rather, as shown by the manufacturer's flight test data, it *will* blank rudder effectiveness, and under certain circumstances, degrade directional control.

**Lack of FOQA monitoring for excessive EPR.** Approximately 80 percent of Delta's MD-80 fleet is monitored by their Flight Operational Quality Assurance (FOQA) program. FAA AC 120-82, *Flight Operational Quality Assurance*, describes a FOQA program as "a voluntary program for the routine collection and analysis of flight operational data to provide more information about, and greater insight into, the total flight operations environment. A FOQA program combines these data with other sources and operational experience to develop objective information to enhance safety, training effectiveness, operational procedures, maintenance and engineering procedures, and air traffic control (ATC) procedures" (AC 120-82, p. 4). "A FOQA program is used to reveal operational situations in which risk is increased in order to enable early corrective action before that risk results in an incident or accident" (AC 120-82, p. 7).

Despite the 1999 MD-80 accident at Little Rock, Arkansas, and despite the Delta MD-88 runway excursion at Cancun – both examples of excessive reverse thrust usage – the Delta MD-88 Fleet Captain told investigators that he was not aware if the company was using FOQA to monitor reverse thrust for EPR exceeding 1.6 or 1.3.[11]

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[9] Operational Factors Group Chairman's Factual Report, Attachment 21. *Boeing Flight Operations Bulletin MD-80-02-03*

[10] Operational Factors Group Chairman's Factual Report, p. 31.

[11] Operational Factors Group Chairman's Factual Report, Attachment 1. *Interview Summaries*, at p.37.

**Summary.** In spite of the above data points, I cannot draw an absolute causal link between them and the Delta 1086 accident. However, I do believe had Delta provided greater attention to the issues outlined above, the likelihood of this accident occurring would have been decreased. To its credit, Delta's response to the findings of NTSB's investigation has been earnest and receptive. It is my hope that remedial action can be taken quickly, so that similar incidents or accidents might be avoided entirely.

Chairman Hart, Vice Chairman Dinh-Zarr, and Member Weener joined in this statement.

# 5. Appendixes

## Appendix A: Investigation

The National Transportation Safety Board (NTSB) was notified of this accident on the morning of March 5, 2015. An NTSB investigator in the New York City area arrived on scene the same day for initial information gathering and stakedown. The go-team launched from the Washington, DC, area the next morning and arrived on scene or at Delta Air Lines headquarters shortly afterward. (The launch was delayed until March 6 due to weather-related transportation impacts from the winter storm.) The following investigative groups were formed: aircraft performance, airports, airworthiness, maintenance records, meteorology, operations/human performance, and survival factors. Also, specialists were assigned to conduct the readout of the flight data recorder and transcribe the cockpit voice recorder at the NTSB's laboratory in Washington, DC.

Parties to the investigation were the Federal Aviation Administration, Delta Air Lines, Boeing, the Air Line Pilots Association, and the Port Authority of New York and New Jersey. No investigative hearing was held for this accident.

# Appendix B: Cockpit Voice Recorder Transcript

The following is a transcript of the L-3/Fairchild FA2100-1020 cockpit voice recorder, serial number 702, installed on Delta Air Lines flight 1086, a Boeing MD-88, N909DL, which departed the runway after landing at LaGuardia Airport in New York, New York, on March 5, 2015.

| LEGEND | |
|---|---|
| **CAM** | Cockpit area microphone voice or sound source |
| **HOT** | Flight crew audio panel voice or sound source |
| **RDO** | Radio transmission from Delta flight 1086 |
| **INT** | Aircraft interphone sound source |
| **ZTL** | Radio transmission from Atlanta Center controller |
| **ZDC** | Radio transmission from Washington Center controller |
| **NYC** | Radio transmission from the New York Approach controller |
| **LGA** | Radio transmission from the LaGuardia Tower controller |
| **-1** | Voice identified as the captain |
| **-2** | Voice identified as the first officer |
| **-3** | Voice identified as first flight attendant |
| **-4** | Voice identified as second flight attendant |
| **-5** | Voice identified as third flight attendant |
| **DL1526** | Radio transmission from Delta flight 1526 |
| **AA1082** | Radio transmission from American flight 1082 |
| **MQ3647** | Radio transmission from Envoy flight 3647 |
| **DL2522** | Radio transmission from Delta flight 2522 |
| **-A** | First identified facility controller |
| **-B** | Second identified facility controller |
| **-C** | Third identified facility controller |
| **-D** | Fourth identified facility controller |
| **-?** | Voice unidentified |
| ***** | Unintelligible word |
| **#** | Expletive |
| @ | Non-pertinent word |
| **( )** | Questionable insertion |
| **[ ]** | Editorial insertion |

Note 1: Times are expressed in eastern standard time (EST).

Note 2: Generally, only radio transmissions to and from the accident aircraft were transcribed unless required for context.

Note 3: Words shown with excess vowels, letters, or drawn out syllables are a phonetic representation of the words as spoken.

Note 4: A non-pertinent word, where noted, refers to a word not directly related to the operation, control or condition of the aircraft.

## CVR Quality Rating Scale

The levels of recording quality are characterized by the following traits of the cockpit voice recorder information:

**Excellent** Virtually all of the crew conversations could be accurately and easily understood. The transcript that was developed may indicate only one or two words that were not intelligible. Any loss in the transcript is usually attributed to simultaneous cockpit/radio transmissions that obscure each other.

**Good** Most of the crew conversations could be accurately and easily understood. The transcript that was developed may indicate several words or phrases that were not intelligible. Any loss in the transcript can be attributed to minor technical deficiencies or momentary dropouts in the recording system or to a large number of simultaneous cockpit/radio transmissions that obscure each other.

**Fair** The majority of the crew conversations were intelligible. The transcript that was developed may indicate passages where conversations were unintelligible or fragmented. This type of recording is usually caused by cockpit noise that obscures portions of the voice signals or by a minor electrical or mechanical failure of the CVR system that distorts or obscures the audio information.

**Poor** Extraordinary means had to be used to make some of the crew conversations intelligible. The transcript that was developed may indicate fragmented phrases and conversations and may indicate extensive passages where conversations were missing or unintelligible. This type of recording is usually caused by a combination of a high cockpit noise level with a low voice signal (poor signal-to- noise ratio) or by a mechanical or electrical failure of the CVR system that severely distorts or obscures the audio information.

**Unusable** Crew conversations may be discerned, but neither ordinary nor extraordinary means made it possible to develop a meaningful transcript of the conversations. This type of recording is usually caused by an almost total mechanical or electrical failure of the CVR system.

| Time and Source | Intra-Aircraft Communication | Time and Source | Over-the-Air Communication |
|---|---|---|---|
| 09:00:47.4 **START OF RECORDING** | | | |
| 09:54:51.8 **START OF INITIAL APPROACH DISCUSSION** | | | |
| 09:54:51.8 **HOT-2** | I doubt we'll hear medium poor but we're at our crosswind limitations for that one. | | |
| 09:54:57.5 **HOT-1** | I'm sorry? | | |
| 09:54:57.8 **HOT-2** | I doubt we will hear medium poor but we're out of crosswind limitations on that one. | | |
| 09:55:02.7 **HOT-1** | okay. | | |
| 09:55:04.6 **HOT-1** | you got a field condition report see what it says if you don't mind. thank you. | | |
| 09:55:09.8 **HOT-2** | I do not mind. | | |
| 09:55:37.5 **HOT-2** | oh I actually didn't know this though. crosswind guidelines are not considered limitations. I did not— I was unaware of that. | | |
| 09:55:50.6 **HOT-1** | uh but we do have a contaminated runway limitation. | | |

| Time and Source | Intra-Aircraft Communication | Time and Source | Over-the-Air Communication |
|---|---|---|---|
| 09:55:54.4 **HOT-2** | yeah I may be looking at that pretty soon too. | | |
| 09:56:47.7 **HOT-2** | it reads just like ATIS. so no it doesn't shed any light on it. | | |
| 09:56:53.4 **HOT-1** | **. | | |
| | | 09:57:29.7 **ZTL** | Delta ten eighty six contact Washington Center one one eight point niner two. |
| | | 09:57:33.7 **RDO-2** | eighteen ninety two. Delta ten eighty six good day. |
| | | 09:57:40.6 **RDO-2** | Washington Center hello Delta ten eighty six checkin' on board three three zero. |
| | | 09:57:45.0 **ZDC-A** | Delta ten eighty six Washington Center roger. flight level three three zero. |
| 09:57:50.7 **HOT-1** | three three zero. | | |
| 09:58:56.1 **HOT-2** | two hundred pounds ahead at GLOVR. | | |
| 09:58:59.6 **HOT-1** | thanks. | | |
| 10:05:24.1 **START OF FULL TRANSCRIPT** | | | |

| Time and Source | Intra-Aircraft Communication | Time and Source | Over-the-Air Communication |
|---|---|---|---|
| 10:05:24.1 **HOT-2** | is there such a thing as light freezing fog? and heavy freezing fog? or is it just— | | |
| 10:05:30.6 **HOT-1** | uh I don't think so. | | |
| 10:05:31.8 **HOT-2** | I mean there's— on this chart I'm just looking at a generic type four moderate and light. moderate to light intensity for freezing fog...ice crystals. it says freezing fog ice crystals. moderate to light. | | |
| 10:05:50.9 **HOT-2** | and I'm guessing it's saying snow without the minus we have to use moderate snow because the visibilities of... | | |
| 10:05:57.7 **HOT-1** | correct. | | |
| 10:05:58.5 **HOT-2** | ...and quarter mile and such. | | |
| 10:05:59.0 **HOT-1** | well we have to use the visibility chart. | | |
| 10:06:02.2 **HOT-2** | uh I think this one kicks us out when it says below a certain thing you have to go with an approved source if I read that correctly. | | |
| 10:06:09.8 **HOT-1** | okay. | | |

| Time and Source | Intra-Aircraft Communication | Time and Source | Over-the-Air Communication |
|---|---|---|---|
| 10:06:10.5 **HOT-2** | and— again I can misread anything @ so by— by all means show me. | | |
| | | 10:06:28.2 **ZDC-B** | Delta ten eighty six is cleared direct to Patuxent. |
| | | 10:06:31.7 **RDO-2** | direct to Patuxent Delta ten eighty six. |
| 10:06:38.9 **HOT-1** | alright @ verified Patuxent. | | |
| 10:06:41.4 **HOT-2** | alright very well. | | |
| 10:06:50.7 **HOT-1** | nav captured. direct Patuxent. | | |
| 10:06:57.7 **HOT-1** | anti ice is comin on. | | |
| 10:07:04.6 **HOT-2** | very well good thanks. | | |
| 10:07:09.0 **HOT-2** | yeah right here it says snowfall intensity is a function of prevailing visibility. do not use uh this chart if visibility is being reduced by snow along with another— other forms of obscuration mist fog etcetera. | | |
| 10:07:22.5 **HOT-1** | yeah here's the chart right here. | | |

| Time and Source | Intra-Aircraft Communication | Time and Source | Over-the-Air Communication |
|---|---|---|---|
| 10:07:26.1 **HOT-1** | visibility is greater than * no. we may have to follow the * yes. no use the snowfall intensity designator approved by the ATIS or whatever. | | |
| 10:07:37.5 **HOT-2** | yeah it says it again here just in different uh a different way. | | |
| 10:07:47.5 **HOT-2** | very well. | | |
| 10:08:17.8 **HOT-2** | this is where I wouldn't mind tablets * when I want to look at the chart I want it to freeze up and reset on me automatically. that's— that's quality manufacture right there. | | |
| 10:08:27.5 **HOT-1** | that's what I'm saying. I think the reliability is going to hurt this thing. | | |
| 10:08:31.0 **HOT-2** | yeah. | | |
| 10:08:31.6 **HOT-1** | because it's gonna get poorer and poorer. | | |
| 10:08:33.5 **HOT-2** | I hope people are re— reporting it yeah. cause that's typical Microsoft. it gets buggier the more you up— you download # on it you know. | | |
| 10:08:41.8 **HOT-1** | yeah I think it was a huge mistake personally but— | | |
| 10:08:44.8 **HOT-2** | yes sir. | | |

| Time and Source | Intra-Aircraft Communication | Time and Source | Over-the-Air Communication |
|---|---|---|---|
| 10:08:45.1 **HOT-1** | you know all the arrival altitudes check— just like I said I put a hard altitude at DAVYS BRAND and two fifty at KORRY just for planning purposes... | | |
| 10:08:54.1 **HOT-2** | okay. | | |
| 10:08:54.5 **HOT-1** | ...ten thousand all hard altitudes. | | |
| 10:09:39.2 **HOT-1** | there it is you know...okay well let's say they say the braking action's fair. | | |
| 10:09:50.9 **HOT-1** | let's just say that for— | | |
| 10:09:52.4 **HOT-2** | we're saying that. | | |
| 10:09:53.9 **HOT-1** | huh? | | |
| 10:09:54.5 **HOT-2** | yes let's say that. | | |
| 10:10:01.5 **HOT-2** | well I realize that I'm supposed to consult my... | | |
| 10:10:05.2 **HOT-1** | uh I was just looking at that. | | |
| 10:10:06.1 **HOT-2** | ...my thing there. | | |

| Time and Source | Intra-Aircraft Communication | Time and Source | Over-the-Air Communication |
|---|---|---|---|
| 10:10:35.6 **HOT-2** | we're at flaps forty and we're gonna call it uh fair you said right? | | |
| 10:10:40.6 **HOT-1** | yeah. | | |
| 10:10:42.1 **HOT-2** | can we call that medium? | | |
| 10:10:44.5 **HOT-1** | yeah. | | |
| 10:10:45.3 **HOT-2** | I like it. | | |
| 10:10:51.3 **HOT-2** | we are gonna land three thousand pounds lighter...make the thirty card yup. | | |
| 10:11:05.1 **HOT-1** | we can't land. | | |
| 10:11:10.4 **HOT-1** | *. | | |
| 10:11:12.5 **HOT-2** | I'll— I'll try to justify one in a second because cause we had to divert because of this situation | | |
| 10:11:20.5 **HOT-1** | I don't think we can even land. | | |
| 10:11:22.4 **HOT-2** | I got uh...maximum autobraking of seventy eight hundred feet. | | |

| Time and Source | Intra-Aircraft Communication | Time and Source | Over-the-Air Communication |
|---|---|---|---|
| 10:11:43.8 **HOT-2** | think you may be right. | | |
| 10:11:55.0 **HOT-1** | I'll be off for just a minute. | | |
| 10:11:56.4 **HOT-2** | alrighty. | | |
| 10:11:56.9 **PA-1** | ladies and gentlemen from the flight deck just an update. we are level at thirty three thousand feet. we're about uh forty miles from Richmond Virginia. we are two hundred and ninety miles from LaGuardia Airport we anticipate right now touching down at uh ten fifty five and having you at the gate right on time at eleven oh clock. that's provided air traffic control allows us to maintain a uh current speed. we've increased the speed a little bit to try to make up some time. so for now we uh we anticipate an on time arrival in LaGuardia. LaGuardia weather reporting overcast skies uh snow. temperature's right at about uh thirty degrees... | | |
| 10:12:10.4 **HOT-2** | on max manual yeah seventy two. | | |
| 10:12:52.0 **HOT-1** | ...or so. | | |
| 10:12:53.3 **HOT-2** | or so. **. | | |
| 10:12:55.4 **HOT-1** | if it's all crosswind like it says it is and if it stays like if it's they say it's anything less than good I— I don't think we're legal to land. | | |

| Time and Source | Intra-Aircraft Communication | Time and Source | Over-the-Air Communication |
|---|---|---|---|
| 10:13:06.1 **HOT-2** | I generally agree with you. I see seventy two hundred feet for max uh manual braking is what I got at a hundred thirty. | | |
| | | 10:13:12.6 **ZDC-B** | Delta ten eighty six contact Washington on uh one two six point eight seven. |
| 10:13:13.2 **HOT-1** | when have you done max manual braking? when have you practiced it? | | |
| | | 10:13:18.3 **RDO-2** | twenty six eighty seven Delta ten eighty six. good day. |
| 10:13:21.6 **HOT-1** | I will never use that column. | | |
| 10:13:22.9 **HOT-2** | la— last year. hah...in this situation. | | |
| | | 10:13:28.1 **RDO-2** | Center hello Delta ten eighty six checking on board level three three zero. |
| | | 10:13:31.8 **ZDC-C** | Delta ten eighty six Washington Center. roger. |
| 10:13:35.6 **HOT-2** | but as I told the captain like I'm setting max— | | |
| 10:13:37.8 **HOT-1** | he's hanging his— he's hanging his # out if he uses the max manual. | | |

| Time and Source | Intra-Aircraft Communication | Time and Source | Over-the-Air Communication |
|---|---|---|---|
| 10:13:41.7 **HOT-2** | well it— it worked out because we got it. we did— we did not land in this situation. we got— we got a good report is what we got cause we— | | |
| 10:13:48.0 **HOT-1** | it's a useless column because we— we don't even practice that in the simulator. | | |
| 10:13:50.9 **HOT-2** | yeah. no I know. | | |
| 10:13:53.0 **HOT-1** | I mean you can say— I mean it— it describes it in the book. | | |
| 10:13:57.3 **HOT-2** | yeah. | | |
| 10:13:58.3 **HOT-1** | but I've been on— I been a captain on this for fifteen years and I've never done it. now I've used max autobrake. | | |
| 10:14:04.8 **HOT-2** | yeah. | | |
| 10:14:05.3 **HOT-1** | and they say use max autobrake then transition then max manual braking. #. | | |
| 10:14:11.6 **HOT-2** | yeah. | | |
| 10:14:12.6 **HOT-1** | you're never using that column. | | |

| Time and Source | Intra-Aircraft Communication | Time and Source | Over-the-Air Communication |
|---|---|---|---|
| 10:14:14.7 **HOT-2** | no I— I tend to agree with you. | | |
| 10:14:19.8 **HOT-2** | I like this one. touchdown speed is v ref forty minus five. so unless you catch that one everyone's already bugging five. you know? now you gotta slow your # down man. this is— this is you got to slow down before you even touch down. | | |
| 10:14:34.2 **HOT-1** | and— and you are going to ILS minimums. so how much runway do we actually have available? | | |
| 10:14:43.0 **HOT-2** | six. right right. here— here's what makes you legal by the way. sea level pressure what do you see? is that two hundred seven feet? or is that— | | |
| 10:14:52.2 **HOT-1** | you know what? I already took that. I already took that but it doesn't make me legal. | | |
| 10:14:56.1 **HOT-2** | it takes you to six point nine. six point nine. | | |
| 10:15:00.3 **HOT-1** | now wait a minute wait a minute. where'd you get six point nine? | | |
| 10:15:02.1 **HOT-2** | you have a hundred and three— you have two hundred and three— no you have a hundred and three feet to spare. what's your problem? [sound of laughter] | | |

| Time and Source | Intra-Aircraft Communication | Time and Source | Over-the-Air Communication |
|---|---|---|---|
| 10:15:07.2 **HOT-1** | no I've got one thirty max autobrake. I never use the max manual. | | |
| 10:15:12.2 **HOT-2** | well yeah but your saying you don't use max— okay well fine fine fine yeah yeah. | | |
| 10:15:14.3 **HOT-1** | no. seven point eight minus four hundred right? | | |
| 10:15:16.4 **HOT-2** | yeah yeah yeah. yeah yeah yeah. | | |
| 10:15:17.7 **HOT-1** | or three hundred... | | |
| 10:15:17.8 **HOT-2** | uh minus— minus three hundred yeah. | | |
| 10:15:18.8 **HOT-1** | ...three hundred. and seven thousand five hundred and I don't even have that in usable runway without flying an ILS. | | |
| 10:15:29.6 **HOT-2** | yeah. that's true. no you don't. | | |
| 10:15:35.6 **HOT-1** | so I'm here to tell you right now if it's less than good we're not landing. | | |
| 10:15:39.0 **HOT-2** | we're going— roger that. I don't blame you one little bit. | | |

| Time and Source | Intra-Aircraft Communication | Time and Source | Over-the-Air Communication |
|---|---|---|---|
| 10:15:44.7 **HOT-2** | I don't— I don't know. yeah. well it's based on optimism. we got to be an optimist. that's why they dispatched us. but still. | | |
| 10:15:55.5 **HOT-2** | uh and— where's— | | |
| 10:15:56.8 **HOT-1** | I'm gonna text him right now. | | |
| 10:15:58.4 **HOT-2** | yeah. get the braking action. | | |
| 10:15:58.6 **HOT-1** | we need the braking action report. | | |
| 10:16:00.9 **HOT-2** | yeah. | | |
| 10:16:06.4 **HOT-2** | but max autobrake sixty one hundred feet if it's good so we're you know— | | |
| 10:16:11.0 **HOT-1** | only if it's in effect. if it's good we're there. | | |
| 10:16:13.8 **HOT-2** | and then we can only subtract two hundred feet on that one for pressure altitude. **. | | |
| 10:17:18.2 **HOT-1** | they put so much gas on this thing, | | |

| Time and Source | Intra-Aircraft Communication | Time and Source | Over-the-Air Communication |
|---|---|---|---|
| 10:17:19.8 **HOT-2** | oh #. the rest of the story is we took off from Atlanta to LaGuardia and uh we ended up holding for forever. every RJ that landed reported uh braking action fair. that's it. that's what they reported. uh we're holding with US Air or United a— a three twenty or something like that and another um eighty eight was with us and um and we— we actually come on a side radio and we all say the same thing 'hey do you guys see the same thing we're seeing?' and they're 'yup. can't land. roger that.' that's what I found. the Airbus has similar limitations that we do so we all divert. we all get gas. we go to divert to Albany. we pick up a # of gas. we come back to LaGuardia. we hold again. hold for— hold for like another hour and a half or something like that. finally an Airbus— different guy— an Airbus decides to make a go for it and uh he lands he reports the braking action good. so we go in right behind him. we land. it was my leg. I flew. it was absolutely a non-event but— but he was the only person that reported good. you know it— it took him to say hey it's good. they were— they were over reporting. and he was right. you know it was fine. there was nothing wrong with— but oh yeah...oh yeah. | | |
| 10:18:50.3 **HOT-1** | no braking action advisory report available. reporting aircraft departing runway four. who the hell cares about *. | | |
| 10:18:58.6 **HOT-2** | right. that's dispatch or is that ATIS? ATIS right? yeah ATIS is saying that. | | |
| 10:19:02.1 **HOT-1** | that's from ATIS. | | |
| 10:19:04.6 **HOT-2** | even though the uh field conditions say the same thing **. | | |

| Time and Source | Intra-Aircraft Communication | Time and Source | Over-the-Air Communication |
|---|---|---|---|
| 10:19:37.2 **HOT-1** | gonna go back and use the uh lav. | | |
| 10:19:40.7 **HOT-2** | potty. alright. | | |
| 10:19:41.8 **HOT-1** | you need to go back? | | |
| 10:19:43.3 **HOT-2** | no. send that cutie from one b up with that— flight attendants are kind of you know...you know. | | |
| 10:19:50.4 **HOT-1** | no I'm not gonna tell her. | | |
| 10:19:52.2 **HOT-2** | # you're no fun. | | |
| 10:19:55.5 **HOT-2** | gonna tell her about max manual braking. | | |
| 10:19:57.4 **INT-3** | @ one left. | | |
| 10:19:58.9 **INT-1** | @ this is @ I need to come back and take a break whenever you can set it up. | | |
| 10:20:02.0 **INT-3** | okay it should be alright in just a minute. let me call you back. | | |
| 10:20:04.5 **INT-1** | thanks. | | |

| Time and Source | Intra-Aircraft Communication | Time and Source | Over-the-Air Communication |
|---|---|---|---|
| 10:20:07.7 **HOT-1** | [discussion regarding cockpit access] | | |
| 10:20:09.9 **HOT-2** | very well. | | |
| 10:20:11.7 **HOT-1** | you have the aircraft. | | |
| 10:20:12.8 **HOT-2** | I have the aircraft. | | |
| 10:20:13.8 **HOT-1** | if you change your mind let me know. | | |
| 10:20:15.4 **HOT-2** | I will. | | |
| 10:20:31.6 **CAM** | [sound similar to flight attendant call chime] | | |
| 10:20:35.6 **INT-1** | hello this is @. | | |
| 10:20:36.8 **INT-3** | [discussion regarding cockpit access] | | |
| 10:20:38.9 **INT-1** | okay. | | |
| 10:20:39.2 **INT-3** | alright. | | |
| 10:20:40.7 **HOT-1** | [discussion regarding cockpit access] | | |

| Time and Source | Intra-Aircraft Communication | Time and Source | Over-the-Air Communication |
|---|---|---|---|
| 10:20:41.9 **HOT-2** | alrighty. | | |
| 10:20:46.0 **HOT** | [sound of oxygen mask momentary operation] | | |
| 10:20:53.7 **HOT-1** | need anything from kitchen? | | |
| 10:20:55.7 **HOT-2** | oh hell no. the way they're cooking? | | |
| 10:20:57.9 **HOT-1** | no I mean drink ice. | | |
| 10:20:59.3 **HOT-2** | yeah I'm good. I'm good. thanks. | | |
| 10:21:01.7 **HOT-1** | I'm putting your hat down here on top of mine **. | | |
| 10:21:04.2 **HOT-2** | okay. | | |
| 10:21:06.1 **CAM-1** | I'll close the door. | | |
| 10:21:13.3 **CAM** | [sound similar to cockpit door closing] | | |
| 10:21:14.8 **HOT-2** | hellooo. | | |
| 10:21:17.9 **CAM-3** | we're actually going to LaGuardia? you said I could give you that look. we're actually going? | | |

| Time and Source | Intra-Aircraft Communication | Time and Source | Over-the-Air Communication |
|---|---|---|---|
| 10:21:22.5 **HOT-2** | you said— you said you could give me that— who said you could give me that look? | | |
| 10:21:24.4 **CAM-3** | I said I keep giving you the look. | | |
| 10:21:26.3 **HOT-2** | I know you keep giving me the look. | | |
| 10:21:27.1 **CAM-3** | what the hell? | | |
| 10:21:28.4 **HOT-2** | but why? | | |
| 10:21:29.6 **CAM-3** | what the hell? | | |
| 10:21:30.5 **HOT-2** | what are you eating? that looks good. | | |
| 10:21:31.9 **CAM-3** | I don't know. it was in the little snack basket. you want one? | | |
| 10:21:34.4 **HOT-2** | no but you should eat it. it looks good. | | |
| 10:21:36.3 **CAM** | [conversation unintelligible due to radio chatter] | | |
| | | 10:21:40.3 **ZDC-C** | Delta ten eighty six cross RIDGY at flight level two seven zero. |

| Time and Source | Intra-Aircraft Communication | Time and Source | Over-the-Air Communication |
|---|---|---|---|
| | | 10:21:45.0 **RDO-2** | cross RIDGY flight level two seven zero. Delta ten eighty six. |
| 10:21:48.6 **HOT-2** | uh yeah that's a little loud. | | |
| 10:21:55.3 **CAM-3** | I was gonna * for a little while. | | |
| 10:21:56.9 **HOT-2** | yeah yeah okay what do you think? alright. | | |
| 10:21:57.9 **CAM-3** | **. it's pretty good * cranberry. | | |
| 10:22:04.8 **CAM-3** | that's pretty decent. right? | | |
| 10:22:08.3 **HOT-2** | like I love shortbread. **. I don't know. tastes good. | | |
| 10:22:15.5 **CAM-3** | **. so are we gonna get stuck in LaGuardia? | | |
| 10:22:18.4 **HOT-2** | oh hell yeah. | | |
| 10:22:20.0 **CAM-3** | no seriously? | | |
| 10:22:21.0 **HOT-2** | I don't know. you know— | | |
| 10:22:22.4 **CAM-3** | you're supposed to know everything. you're the pilot. | | |

| Time and Source | Intra-Aircraft Communication | Time and Source | Over-the-Air Communication |
|---|---|---|---|
| 10:22:23.6 **HOT-2** | well...hold on. | | |
| 10:22:26.8 **CAM-3** | or is it getting warmer? I feel like it's getting warmer. | | |
| 10:22:29.2 **HOT-2** | you would be incorrect my dear. | | |
| 10:22:30.9 **CAM-3** | I thought it would. I thought you said it was thirty. thirty two— no thirty four. | | |
| 10:22:38.1 **HOT-2** | thirty. minus one now. no it's minus three. it's colder. twenty seven. | | |
| 10:22:43.6 **CAM-3** | I don't want to stay in New York though. | | |
| 10:22:46.3 **HOT-2** | but you might be stuck with us. and look how lucky you'd be. | | |
| 10:22:48.1 **CAM-3** | that would be so much fun. | | |
| 10:22:49.1 **HOT-2** | wouldn't that be lovely? | | |
| 10:22:50.0 **CAM-3** | it would. | | |
| 10:22:50.8 **HOT-2** | who was I telling— I wasn't telling you was I? my uh buddy got stuck in LaGuardia during one of those last snows. forty hours at the Crowne Plaza. | | |

| Time and Source | Intra-Aircraft Communication | Time and Source | Over-the-Air Communication |
|---|---|---|---|
| 10:22:58.5 **CAM-3** | nuh-uh. **. they would have us at the Roosevelt *. | | |
| 10:23:03.6 **HOT-2** | that would never happen. | | |
| 10:23:04.7 **CAM-3** | **. | | |
| 10:23:06.5 **HOT-2** | I like the Roosevelt. it's okay. it's not a four star. | | |
| 10:23:09.5 **CAM-3** | **. | | |
| 10:23:11.3 **HOT-2** | we don't talk about that. we don't talk about that. | | |
| 10:23:14.5 **INT-2** | this is @. | | |
| 10:23:15.3 **INT-4** | it's @ in the back. would you mind cooling it off back here? it's really warm. | | |
| 10:23:20.8 **INT-2** | cool it off back there. you got it. | | |
| 10:23:22.0 **INT-5** | hello? | | |
| 10:23:23.0 **INT-2** | yup it's cooling down. | | |
| 10:23:24.5 **INT-4** | okay. can't hear a word you just said. I hope you heard me. | | |

| Time and Source | Intra-Aircraft Communication | Time and Source | Over-the-Air Communication |
|---|---|---|---|
| 10:23:27.7 **INT-5** | hello? | | |
| 10:23:29.0 **INT-2** | yes I did. *. | | |
| 10:23:30.9 **INT-4** | okay thanks. | | |
| 10:23:32.8 **CAM-3** | she's having a flash because it's not. ***. | | |
| 10:23:41.3 **HOT-2** | not— not what else is looking **. | | |
| 10:23:46.5 **CAM-3** | [sound of laughter] | | |
| 10:23:47.9 **HOT-2** | I'm not so confident of you. [sound of laughter] | | |
| 10:23:49.8 **CAM** | [sound of intercom chime] | | |
| 10:23:50.4 **CAM-3** | oh are they ready? | | |
| 10:23:51.4 **INT-2** | hi this is @. | | |
| | | 10:23:52.9 **ZDC-C** | Delta ten eighty six at RIDGY maintain a speed of two five zero knots. There's a chance you're gonna have to hold up near Robbinsville. |

| Time and Source | Intra-Aircraft Communication | Time and Source | Over-the-Air Communication |
|---|---|---|---|
| 10:23:53.0 **INT-1** | this is @. *. | | |
| 10:23:54.3 **INT-2** | okay. | | |
| 10:23:55.6 **CAM-3** | you have to potty? | | |
| | | 10:23:59.8 **RDO-2** | alright. Chance of holding. Two hundred fifty knots at RIDGY. We'll do that. Delta ten eighty six. |
| 10:24:03.9 **HOT-2** | I'm good thank you. | | |
| 10:24:04.7 **CAM-3** | okay. | | |
| 10:24:05.3 **CAM-1** | ***. | | |
| 10:24:06.7 **CAM-3** | no no no. your fine. | | |
| 10:24:08.2 **CAM-3** | **. | | |
| 10:24:09.9 **HOT-2** | I'm good. I won't be coming out. | | |
| 10:24:11.2 **CAM-3** | okay. | | |
| 10:24:15.8 **CAM-1** | **. | | |

| Time and Source | Intra-Aircraft Communication | Time and Source | Over-the-Air Communication |
|---|---|---|---|
| 10:24:17.8 **CAM-1** | huh? | | |
| 10:24:18.3 **CAM-3** | **. | | |
| 10:24:21.4 **CAM** | [sound similar to cockpit door closing] | | |
| 10:24:21.9 **HOT** | [sound similar to momentary oxygen mask operation] | | |
| 10:24:23.0 **HOT-2** | so I don't know if you called at the same time the dingbat from the back called or not but uh. Apparently you were stepping on each other and then ATC is naturally calling at the same time. We are um heading downhill because they— | | |
| | | 10:24:35.3 **ZDC-C** | Delta ten eighty six contact Washington Center on one two five four five she'll give you an update up ahead there. |
| 10:24:39.4 **HOT-1** | RIDGY at two seven oh. I see it. | | |
| | | 10:24:40.9 **RDO-2** | twenty five forty five. Uh Delta ten eighty six roger we're descending now. |
| 10:24:46.3 **HOT-2** | yeah it all happened at once there. | | |
| | | 10:24:49.6 **RDO-2** | Center hello Delta ten eighty six checkin' on board we're descending out of three three zero for two seven zero and two hundred fifty knots at RIDGY. |

| Time and Source | Intra-Aircraft Communication | Time and Source | Over-the-Air Communication |
|---|---|---|---|
| 10:24:56.1 **HOT-2** | stand by for holding. | | |
| | | 10:24:56.5 **ZDC-D** | Delta ten eighty six Washington Center roger. * currently holding at LaGuardia for the uh runway clean up. I'm gonna call and get an update and see how much longer they're gonna hold. so for now I've got holding instructions. advise when ready to copy. |
| 10:25:08.4 **HOT-2** | you ready to copy? | | |
| 10:25:08.9 **HOT-1** | yeah. | | |
| | | 10:25:09.7 **RDO-2** | ready to copy Delta ten eighty six. |
| | | 10:25:11.4 **ZDC-D** | Delta ten eighty six clearance limit is Robbinsville. Hold southwest as published. maintain flight level two seven zero. expect further clearance one five five five. |
| | | 10:25:24.8 **RDO-2** | alright uh we'll hold at Robbinsville southwest as published at two seven zero. EFC of fifteen fifty five and we'd like to uh reduce speed now if that's okay. Delta ten eighty six. |
| 10:25:34.7 **HOT-1** | the clearance limit's Robbinsville. | | |
| 10:25:36.9 **HOT-2** | you can split it whenever you want. | | |

| Time and Source | Intra-Aircraft Communication | Time and Source | Over-the-Air Communication |
|---|---|---|---|
| 10:25:38.4 **HOT-1** | and they wanted RIDGY at two fifty also? | | |
| 10:25:41.8 **HOT-2** | two hundred fifty knots at RIDGY uh see dih dih if you want— you got that available. | | |
| 10:25:47.6 **HOT-1** | you got those. Thanks. | | |
| 10:25:48.4 **HOT-2** | yup they're on. | | |
| 10:25:54.5 **HOT-1** | I would have told him unable two fifty at RIDGY. | | |
| 10:25:56.9 **HOT-2** | I just— he was just giving it to me left and right so I didn't have a chance to even look. | | |
| 10:26:11.9 **HOT-2** | oh I'm sorry. do you mind if I program this in? I'm sorry I didn't realize **. | | |
| 10:26:14.0 **HOT-1** | no I don't want you to put 'em in. we got— we got— uhh. | | |
| 10:26:15.8 **CAM** | [sound similar to altitude alert] | | |
| 10:26:18.7 **HOT-1** | we got plenty of time. | | |
| 10:26:22.1 **HOT-2** | alright you're captured. It's gonna be a hard one. two seven zero. | | |

| Time and Source | Intra-Aircraft Communication | Time and Source | Over-the-Air Communication |
|---|---|---|---|
| 10:26:24.7 **HOT-1** | it better capture. | | |
| 10:26:27.0 **HOT-2** | yup it's gonna capture alright. | | |
| 10:26:33.4 **HOT-1** | you gotta be # me. | | |
| 10:26:35.4 **HOT** | [sound similar to altitude alert] altitude. [automated voice]<br>[sound similar to altitude alert] | | |
| 10:26:37.6 **CAM** | [sound similar to stab trim in motion] | | |
| 10:26:39.9 **HOT** | [sound similar to altitude alert] altitude. [automated voice]<br>[sound similar to altitude alert] altitude. [automated voice]<br>[sound similar to altitude alert] altitude. [automated voice] | | |
| 10:26:56.1 **CAM** | [sound similar to stab trim in motion] | | |
| 10:26:56.8 **HOT-1** | come on you #. | | |
| 10:27:01.5 **CAM** | [sound similar to stab trim in motion] | | |
| 10:27:08.1 **CAM** | [sound similar to stab trim in motion] | | |
| 10:27:25.5 **HOT-1** | nice heads up from the dispatcher. the #. | | |

| Time and Source | Intra-Aircraft Communication | Time and Source | Over-the-Air Communication |
|---|---|---|---|
| 10:27:27.9 **HOT-2** | yeah. | | |
| | | 10:27:35.2 **ZDC-D** | Delta ten eighty six you think you'll be able to fly uh ILS to one three? |
| 10:27:38.8 **HOT-1** | I don't know. what's the— what's the braking action? | | |
| | | 10:27:41.0 **RDO-2** | say again for Delta ten eighty six. |
| | | 10:27:42.4 **ZDC-D** | Delta ten eighty six are you able ILS one three into LaGuardia? |
| | | 10:27:46.5 **RDO-2** | uh depends on braking action for delta ten eighty six. do you have reports for us? |
| | | 10:27:53.9 **ZDC-D** | I don't have a braking action right now. um all I'm asking is if you are going to be able to do runway one three into LaGuardia ILS. I'll get the RVR for you momentarily. |
| 10:28:00.9 **HOT-2** | yeah sure. | | |
| 10:28:03.8 **HOT-1** | yeah if you give us— | | |

| Time and Source | Intra-Aircraft Communication | Time and Source | Over-the-Air Communication |
|---|---|---|---|
| | | 10:28:04.7 **RDO-2** | yeah we can certainly do the ILS to one three for Delta ten eighty six unless you know something we don't know but we need uh braking action reports. we're trying to get them from dispatch as well. |
| | | 10:28:13.0 **ZDC-D** | roger. |
| 10:28:15.8 **HOT-2** | does she know something— | | |
| | | 10:28:16.3 **ZDC-D** | and Delta ten eighty six descend and maintain flight level two zero zero. |
| | | 10:28:20.0 **RDO-2** | descend to flight level two zero zero Delta ten eighty six and uh holding instructions remain the same? |
| | | 10:28:25.4 **ZDC-D** | everything remains the same for now. we're in the hold until we come out of hold. that is for planning purposes is what LaGuardia's planning on doing. ILS one three when they open it up. |
| | | 10:28:34.1 **RDO-2** | I understand. descending to level two zero zero. Delta ten eighty six. |
| 10:28:37.4 **HOT-1** | you know that's un— unexcusable. | | |

| Time and Source | Intra-Aircraft Communication | Time and Source | Over-the-Air Communication |
|---|---|---|---|
| 10:28:48.4 **HOT-2** | it does— does it not seem to you like everybody's been caught off guard? besides the fact we all knew this was gonna happen. | | |
| 10:28:56.6 **HOT-1** | say again? | | |
| 10:28:57.9 **HOT-2** | said it seems like everybody else is sort of surprised by this. you know we knew the weather was— this is New York. I mean what do you think happens here? | | |
| 10:29:28.4 **HOT-2** | one thirty clean speed two thirty four. we're good on speed. two fifty. okay. | | |
| 10:29:41.4 **HOT-1** | max hold's two ten at Robbinsville. right turns. I don't see any DME published. | | |
| 10:29:52.6 **HOT-2** | * timing *. | | |
| 10:29:57.4 **HOT-1** | well we'll ask for— we'll ask for legs. | | |
| | | 10:30:00.8 **ZDC-D** | Delta fifteen twenty six. go ahead sir. |
| | | 10:30:02.9 **DL1526** | yeah we're looking at our gas. we can only hold for maybe twenty more minutes then we'll have to go to JFK... |
| 10:30:03.0 **CAM** | [sound similar to stab trim in motion] | | |

| Time and Source | Intra-Aircraft Communication | Time and Source | Over-the-Air Communication |
|---|---|---|---|
| 10:30:09.0 **HOT-2** | she ain't gonna care. | | |
| 10:30:15.5 **HOT-1** | zero six eight inbound. right turns at Robbinsville. two ten max hold between six and fourteen othwerwise we can hold at two fifty. so for now we're okay. | | |
| 10:30:33.6 **HOT-1** | what did he say? | | |
| 10:30:35.5 **HOT-2** | he's got to go. he can't hold. | | |
| 10:30:37.6 **HOT-1** | no no no no no. I'm talking about the dispatcher. | | |
| 10:30:38.3 **HOT-2** | who? this guy? | | |
| 10:30:45.9 **HOT-1** | special...quarter mile...braking advisories in effect. now what did he say? | | |
| 10:30:59.1 **HOT-1** | uplink message...I'll pass the braking action along as soon as I get one. | | |
| 10:31:08.0 **HOT-1** | alright. why didn't you advise us of this earlier? I— I— I don't even want to— I don't even want to talk to him. | | |
| 10:31:14.2 **HOT-2** | don't **. | | |

| Time and Source | Intra-Aircraft Communication | Time and Source | Over-the-Air Communication |
|---|---|---|---|
| 10:31:15.3 **HOT-1** | they're useless. | | |
| 10:31:16.3 **HOT-2** | they're useless. | | |
| 10:31:16.9 **HOT-1** | okay we're going to two zero zero. it's IAS. it's descending. it's armed...uh our alternate is Albany. Albany right? | | |
| 10:31:26.1 **HOT-2** | and Syracuse yes. both Albany and Syracuse. that's correct. | | |
| 10:31:28.9 **HOT-1** | ummm... | | |
| 10:31:50.3 **HOT-1** | I need to see what the burn is to Albany when you get a chance. when you can tell me. | | |
| 10:31:54.7 **HOT-2** | sure I will tell you right here boss. | | |
| 10:32:06.7 **HOT-2** | alright to Albany— | | |
| | | 10:32:09.3 **ZDC-D** | Delta ten eighty six descend and maintain one seven thousand. the altimeter at Philadelphia is three zero one two. one seven thousand. |
| 10:32:15.7 **HOT-2** | seventeen thousand. | | |

| Time and Source | Intra-Aircraft Communication | Time and Source | Over-the-Air Communication |
|---|---|---|---|
| | | 10:32:18.0 **RDO-2** | descend to seven thousand. thirty thirteen on the meter. Delta ten eighty six. |
| | | 10:32:21.5 **ZDC-D** | seventeen. one seven thousand. correct? |
| 10:32:21.7 **HOT-1** | one seven thousand. descending— | | |
| | | 10:32:25.0 **RDO-2** | one seven thousand feet for Delta ten eighty six. correct. |
| 10:32:29.5 **HOT-2** | oops. alright. Albany? you're gonna burn four thousand pounds. | | |
| 10:32:34.8 **HOT-1** | so that's nine thousand from over uh...there. the burn from Robbinsville to uh LaGuardia is what? | | |
| 10:32:58.3 **HOT-2** | eighteen five to get us there. so that's two zero zero. so basically two thousand pounds. | | |
| 10:33:10.2 **HOT-1** | gonna be eleven...to land with five...check my math. | | |
| 10:33:17.6 **HOT-2** | yeah. | | |
| 10:33:24.1 **HOT-1** | descent checklist. just the altimeter for now. | | |
| 10:33:28.6 **HOT-2** | sure. | | |

| Time and Source | Intra-Aircraft Communication | Time and Source | Over-the-Air Communication |
|---|---|---|---|
| 10:33:31.7 **HOT-2** | altimeters? | | |
| 10:33:32.9 **HOT-1** | three zero one three. is crosschecked. | | |
| 10:33:35.3 **HOT-2** | thirty thirteen is crosschecked. | | |
| 10:33:46.2 **HOT-2** | alright. going to Albany four thousand pounds. | | |
| 10:33:56.8 **HOT-2** | eighty five...ten five. and you say eleven? what did you—what did you say? | | |
| 10:34:01.0 **HOT-1** | wha— what? | | |
| 10:34:02.9 **HOT-2** | what was your number? | | |
| 10:34:03.8 **HOT-1** | well you gave me uh four thousand pounds to burn. | | |
| 10:34:08.6 **HOT-2** | to get to Albany? | | |
| 10:34:10.2 **HOT-1** | and land with five. | | |
| 10:34:10.2 **HOT-2** | yup. | | |
| 10:34:11.8 **HOT-1** | plus two from Robbinsville gives us eleven. | | |

| Time and Source | Intra-Aircraft Communication | Time and Source | Over-the-Air Communication |
|---|---|---|---|
| 10:34:11.9 **HOT-2** | land with five. | | |
| 10:34:13.8 **HOT-2** | sure. eleven thousand. I like eleven. | | |
| 10:34:16.2 **HOT-1** | okay? | | |
| 10:34:17.7 **HOT-1** | and Albany is uh ten miles few broken. uh good weather in Albany. that's fine. | | |
| 10:34:17.8 **HOT-2** | call bingo. | | |
| | | 10:34:23.3 **ZDC-D** | Delta ten eighty six cross BRAND at eleven thousand. that's one one thousand and that will be your holding altitude over Robbinsville. eleven thousand. |
| | | 10:34:31.4 **RDO-2** | okay cross BRAND at eleven thousand. Delta ten eighty six. and uh— |
| 10:34:35.2 **HOT-2** | do you want ten mile legs? | | |
| 10:34:36.6 **HOT-1** | yeah ask for ten m— | | |
| | | 10:34:36.9 **RDO-2** | requesting ten mile legs on the hold for Delta ten eighty six. |
| | | 10:34:40.0 **ZDC-D** | ten eighty six I need you to hold as published. |

| Time and Source | Intra-Aircraft Communication | Time and Source | Over-the-Air Communication |
|---|---|---|---|
| 10:34:42.6 **HOT-1** | alright. | | |
| | | 10:34:43.3 **RDO-2** | as published. ten eighty six. |
| 10:34:46.3 **HOT-2** | seventeen thousand eleven thousand. cross BRAND at eleven thousand feet. | | |
| 10:34:50.2 **HOT-1** | yeah uh we got it. | | |
| 10:34:52.2 **HOT-2** | yeah...alright. | | |
| 10:34:54.9 **HOT-1** | eleven thousand. if we need to— I'll put drag out. whatever we did. the hold's in there. right turns. hold as published. we'll have to slow to two ten at Robbinsville as well. | | |
| 10:35:26.8 **HOT-2** | why is she asking me if we can do ILS to one three? runway end identifier lights are out of service. | | |
| 10:35:33.1 **HOT-1** | so... | | |
| 10:35:40.6 **HOT-2** | edge markings are obscured. | | |
| 10:35:57.9 **HOT-?** | #. | | |

| Time and Source | Intra-Aircraft Communication | Time and Source | Over-the-Air Communication |
|---|---|---|---|
| 10:36:59.9 **HOT-1** | BRAND at eleven. two ten for the hold. that's all gonna be in there. | | |
| 10:37:05.5 **HOT-2** | yes sir. | | |
| 10:37:06.8 **HOT-1** | EFC was... | | |
| 10:37:09.3 **HOT-2** | fifteen fifty five. | | |
| 10:37:19.0 **HOT-1** | [sound similar to sigh] | | |
| 10:37:30.4 **HOT-1** | alright we got uh icing here. | | |
| | | 10:37:31.5 **ZDC-D** | Delta fifteen twenty six you're now cleared to LaGuardia via the KORRY three. maintain one zero thousand. and uh they're gonna try to work you in as soon as they can. they're still— almost finished with the cleanup. |
| 10:37:34.6 **HOT-2** | okay. | | |
| 10:37:44.4 **HOT-2** | got a flow light. | | |
| 10:37:45.0 **HOT-1** | what clean up? | | |
| 10:37:47.2 **HOT-2** | flow light in to uh. | | |

| Time and Source | Intra-Aircraft Communication | Time and Source | Over-the-Air Communication |
|---|---|---|---|
| 10:37:49.3 **HOT-1** | what's that? | | |
| 10:37:50.1 **HOT-2** | got a flow light. | | |
| 10:37:50.9 **HOT-1** | alright. yeah. we'll take care of that in a minute here. | | |
| 10:37:55.7 **HOT-1** | let's go slats extend. | | |
| 10:37:57.0 **HOT-2** | here we go. speed checks. here come slats. | | |
| 10:38:18.9 **INT-3** | @ one left. | | |
| 10:38:19.7 **INT-1** | @ no this is not initial. this is holding. I just uh. we're holding. | | |
| 10:38:26.3 **INT-3** | oh okay. alright are you going to make that announcement or do you want me to? | | |
| 10:38:29.1 **INT-1** | yeah when we get to— no I'll make the announcement. but it's— it's gonna be a while. they're— they're— they're screwing around up here. I'll make the announcement. | | |
| 10:38:37.9 **INT-3** | okay alright. | | |

| Time and Source | Intra-Aircraft Communication | Time and Source | Over-the-Air Communication |
|---|---|---|---|
| 10:39:28.1 **HOT-1** | RVR of twenty four hundred. flight director or autopilot or HUD dih dih. yeah you see— twenty four hundred RVR. unless the RVR is— | | |
| 10:39:40.4 **HOT-2** | did you hear a report from her yet? I have not. | | |
| 10:39:41.8 **HOT-1** | no. she's— she's— | | |
| 10:39:43.1 **HOT-2** | promised to get back to everybody but she hasn't. | | |
| 10:39:44.1 **HOT-1** | she's— she's just dorkin' it up. they're useless. dispatcher's useless. he should have gave us a head's up they were holding. | | |
| | | 10:39:51.6 **ZDC-D** | Delta ten eighty two descend and maintain flight level one niner zero. |
| 10:39:54.1 **HOT-2** | hold on. that's ten eighty two. | | |
| | | 10:39:57.4 **ZDC-D** | uh American— American ten eighty two descend and maintain flight level one niner zero. |
| | | 10:40:01.4 **AA1082** | descend to one niner zero for American ten eighty two. is the holding for run— for plowing? |
| | | 10:40:05.3 **ZDC-D** | it's— it's uh holding for runway cleanup. |

| Time and Source | Intra-Aircraft Communication | Time and Source | Over-the-Air Communication |
|---|---|---|---|
| | | 10:40:08.3 **AA1082** | copy that. do you have an RVR for runway— are they still landing to runway one three? |
| | | 10:40:12.5 **ZDC-D** | last re— last we had was uh six thousand. |
| 10:40:15.6 **HOT-2** | six thousand. | | |
| 10:40:40.7 **HOT-2** | okay. that's all that. currently charlie eighteen is our gate. | | |
| 10:40:50.9 **HOT-1** | okay. | | |
| 10:40:52.4 **HOT-2** | we keep it that'd be nice. | | |
| | | 10:41:20.7 **ZDC-D** | Delta ten eighty six descend and maintain one zero thousand. ten thousand. |
| | | 10:41:24.6 **RDO-2** | descend to ten thousand. Delta ten eighty six. |
| 10:41:26.7 **HOT-2** | okay slow down for your hold as well. | | |
| 10:41:27.9 **HOT-1** | yup. | | |
| 10:41:31.5 **HOT-1** | ten thousand | | |

| Time and Source | Intra-Aircraft Communication | Time and Source | Over-the-Air Communication |
|---|---|---|---|
| 10:41:32.3 **HOT-2** | ten thousand. altitude's armed. | | |
| | | 10:42:05.3 **ZDC-D** | Delta ten eighty six. |
| 10:42:07.5 **HOT-1** | what? | | |
| | | 10:42:09.8 **ZDC-D** | Delta ten eighty six. you're now cleared to LaGuardia via the KORRY three arrival. descend and maintain ten thousand at this time. |
| 10:42:12.0 **CAM** | [sound similar to altitude alert] | | |
| | | 10:42:17.1 **RDO-2** | alright we are cleared to LaGuardia via the KORRY three arrival. descend to ten thousand. Delta ten eighty six. |
| 10:42:21.7 **HOT-2** | it's turning on you. | | |
| | | 10:42:22.2 **ZDC-D** | ten eighty six contact New York Approach one two seven point three. good day. |
| 10:42:23.0 **HOT-1** | yeah. | | |
| | | 10:42:26.1 **RDO-2** | twenty seven three. Delta ten eighty six good day. |

| Time and Source | Intra-Aircraft Communication | Time and Source | Over-the-Air Communication |
|---|---|---|---|
| | | 10:42:33.6 **RDO-2** | New York Delta ten eighty six checkin' on board ten thousand five hundred for ten thousand via the KORRY three. we have papa. |
| | | 10:42:39.3 **NYC** | Delta ten eighty six New York Approach. altimeter's three zero one three. descend and maintain seven thousand. |
| | | 10:42:43.9 **RDO-2** | thirty thirteen descend to seven thousand. Delta ten eighty six. |
| 10:42:47.3 **HOT-1** | seven thousand. | | |
| 10:42:47.5 **HOT-2** | seven thousand. altitude's armed. vert speed. | | |
| 10:42:49.8 **HOT-1** | it's descending and armed. | | |
| 10:42:51.5 **HOT-2** | *. | | |
| 10:42:53.7 **HOT-2** | alright you want to go through the approach checklist? | | |
| 10:42:55.7 **HOT-1** | no. | | |
| 10:42:56.3 **HOT-2** | er descent checklist I mean. | | |
| 10:42:57.3 **HOT-1** | uh not yet. | | |

| Time and Source | Intra-Aircraft Communication | Time and Source | Over-the-Air Communication |
|---|---|---|---|
| 10:43:06.2 **PA-1** | ladies and gentlemen they were gonna put us in holding and they just took us out of holding so we're uh back direct to LaGuardia. should be touching down in about twenty minutes or so. flight attendants uh please prepare the cabin uh for arrival. gate charlie eighteen will be our arrival gate. charlie eighteen. | | |
| 10:43:40.1 **HOT-1** | nine for seven. it's armed. we're tracking. let's see. uh ILS one three. eleven dash two. fifteen August twenty eighteen. one oh eight five. one thirty four's the course. it's uh two hundred fourteen feet is the baro. uh we have twenty four hundred RVR's required. braking action of good or better is required. it's a MALSR with a PAPI on the left that's not coincident. we know about the runway avail— we talked about that. missed approach. climb to eight hundred. climbing left turn two thousand outbound LaGuardia zero four three to GREKO. that's in the box we'll be able to nav it up. min safe over the city three thousand. over the water twenty one hundred. flaps forty. maximum autobrake. right turnoff. probably at the end...whiskey or zulu...and uh charlie eighteen's the gate. it's over in here. okay. | | |
| 10:44:59.7 **HOT-2** | yup. | | |
| 10:45:00.6 **HOT-1** | and uh...green pages...three one one three. don't see anything for one three...KORRY...one three autoland procedure not authorized...we're not gonna do an autoland. | | |
| 10:45:25.7 **HOT-2** | no. | | |

| Time and Source | Intra-Aircraft Communication | Time and Source | Over-the-Air Communication |
|---|---|---|---|
| 10:45:26.3 **HOT-1** | okay. D ninety...I don't see anything else. okay let's finish the descent checklist. | | |
| 10:45:32.6 **HOT-2** | alright alt— | | |
| 10:45:33.0 **HOT-1** | oh two thirty four...one eighty seven...one fifty eight...one forty five. flaps forty. | | |
| 10:45:38.2 **CAM** | [sound similar to seatbelt sign] | | |
| | | 10:45:38.4 **NYC** | Delta fifteen twenty six we just received poor braking action. uh going to be a change of plans. fly heading zero eight zero join LaGuardia two— stand by. |
| 10:45:46.8 **HOT-1** | alright we can't land with poor. we know that. we saw this coming. man. | | |
| 10:45:51.3 **HOT-2** | yeah that's what I'm saying. they caught everybody by surprise. | | |
| 10:45:51.8 **HOT-1** | and th— this is the dispatch— this is the dispatcher's fault. | | |
| 10:45:54.8 **HOT-2** | that's— | | |
| 10:45:55.6 **HOT-1** | it is. | | |

| Time and Source | Intra-Aircraft Communication | Time and Source | Over-the-Air Communication |
|---|---|---|---|
| 10:45:56.0 **HOT-2** | for s— I mean ATC and everything. | | |
| | | 10:45:56.6 **NYC** | Envoy thirty six forty seven. turn left heading three two zero. would you be able to take poor braking action? |
| 10:45:56.7 **HOT-1** | alright. so anyway. if we can do this that's fine. | | |
| 10:46:01.7 **HOT-2** | nope. | | |
| 10:46:02.4 **HOT-1** | nobody. I don't think anybody— | | |
| | | 10:46:02.5 **MQ3647** | stand by thirty six forty seven. zero four zero in the meantime. I mean uh— what was that heading again? |
| 10:46:06.1 **HOT-1** | when you get a chance tell her we cannot. rest of the descent check. | | |
| | | 10:46:08.8 **NYC** | three two zero. |
| 10:46:09.2 **HOT-2** | oh yeah. exactly. altimeters? | | |
| 10:46:09.9 **HOT-1** | we have one thirty two. and bug one thirty seven. | | |
| | | 10:46:11.3 **MQ3647** | stand by thirty six forty seven. |

| Time and Source | Intra-Aircraft Communication | Time and Source | Over-the-Air Communication |
|---|---|---|---|
| 10:46:13.1 **HOT-1** | uh three zero one three is crosschecked. | | |
| | | 10:46:14.3 **MQ3647** | you have the winds thirty six forty seven? |
| 10:46:16.3 **HOT-2** | thirty thirteen is crosschecked. minimums? | | |
| | | 10:46:18.3 **NYC** | zero three zero at one three. |
| 10:46:20.2 **HOT-1** | uh...what'd I say. baro for now two fourteen is crosschecked. | | |
| | | 10:46:23.5 **NYC** | Delta fifteen twenty six can you take braking action poor? |
| | | 10:46:26.9 **DL1526** | negative. |
| | | 10:46:27.3 **NYC** | okay fly heading zero eight zero. join LaGuardia two two four radial. direct to PROUD and hold at PROUD as published. |
| 10:46:30.8 **HOT-2** | uh of baro DA of uh two fourteen is crosschecked. landing data? | | |
| | | 10:46:35.1 **DL1526** | okay Delta fifteen twenty six zero eight— you know what we just need to go to Hartford. uh Bradley. |

| Time and Source | Intra-Aircraft Communication | Time and Source | Over-the-Air Communication |
|---|---|---|---|
| | | 10:46:41.3 **NYC** | okay Delta fifteen twenty six. and uh maintain five thousand. just fly heading zero four zero for now. |
| 10:46:46.3 **HOT-2** | landing data? | | |
| 10:46:48.0 **HOT-1** | flaps forty. v ref one thirty two crosschecked. | | |
| 10:46:50.6 **HOT-2** | flaps forty. ref one thirty two is crosschecked. approach briefing complete. seatbelt sign on. engine synch's off. pressurization panel set. hydraulic panel set. descent checklist complete. | | |
| | | 10:46:54.6 **MQ3647** | ** thirty six forty seven negative on poor braking action. |
| 10:47:02.1 **HOT-1** | I'll set up to hold at PROUD for now. let's see... | | |
| | | 10:47:02.4 **NYC** | thirty six forty seven. Airbus that uh just rolled out reported braking action good. |
| 10:47:07.7 **HOT-2** | alright *. | | |
| | | 10:47:07.8 **MQ3647** | we can take it then. |
| | | 10:47:09.0 **NYC** | Delta fifteen twenty six did you copy? |

| Time and Source | Intra-Aircraft Communication | Time and Source | Over-the-Air Communication |
|---|---|---|---|
| | | 10:47:12.1 **DL1526** | uh braking action good is good for us Delta fifteen twenty six. okay we're climbing back to five thousand turning to zero four zero heading. |
| | | 10:47:17.6 **NYC** | Delta fifteen twenty six thank you. continue left turn to zero two zero. |
| 10:47:22.0 **HOT-1** | we're out of the icing but we'll leave this on. okay? | | |
| 10:47:25.0 **HOT-2** | okay. | | |
| 10:47:26.4 **HOT-1** | approach checklist. | | |
| 10:47:28.3 **HOT-2** | alrighty sir this is— | | |
| 10:47:29.3 **HOT-1** | descent checklist is complete right? | | |
| 10:47:30.2 **HOT-2** | yeah this has been on the whole time. | | |
| 10:47:31.2 **HOT-1** | uh doesn't matter because we're— we're out of it now. so we're fine | | |
| 10:47:33.5 **HOT-2** | yeah. | | |

| Time and Source | Intra-Aircraft Communication | Time and Source | Over-the-Air Communication |
|---|---|---|---|
| | | 10:47:33.6 **NYC** | Delta ten eighty six descend and maintain four thousand. fly heading zero two zero. |
| | | 10:47:37.5 **RDO-2** | descend to four thousand. heading zero two zero. Delta ten eighty six. |
| 10:47:40.8 **HOT-2** | four thousand. altitude is armed. | | |
| 10:47:43.0 **HOT-1** | four thousand descending and armed. | | |
| 10:47:43.4 **HOT-2** | heading zero two zero. | | |
| 10:47:47.1 **HOT-2** | flight and nav instruments? | | |
| 10:47:52.5 **HOT-1** | verified. | | |
| 10:47:53.4 **HOT-2** | verified. spoilers retracted disarmed. cabin notification? | | |
| 10:47:57.6 **HOT-1** | is complete. | | |
| 10:47:59.0 **HOT-2** | altimeters? | | |
| 10:48:01.5 **HOT-1** | thirty thirteen is last I got. | | |

| Time and Source | Intra-Aircraft Communication | Time and Source | Over-the-Air Communication |
|---|---|---|---|
| 10:48:04.7 **HOT-2** | thirty thirteen crosschecked. | | |
| 10:48:05.3 **HOT-1** | crosschecked. | | |
| 10:48:07.1 **HOT-2** | approach checklist complete. your speed's creeping up on you if you care. | | |
| 10:48:09.7 **HOT-1** | thank you. | | |
| 10:48:33.2 **HOT-1** | let's see if we were go— let me just check one thing here. Albany we would land with thirteen. | | |
| | | 10:48:41.0 **DL2522** | Approach Delta twenty five twenty two. just to reconfirm the braking action at LaGuardia is good? |
| 10:48:44.6 **HOT-2** | two hundred and forty knots. | | |
| | | 10:48:45.4 **NYC** | Delta twenty five twenty two. affirmative. last aircraft to land an Airbus reported braking action good. |
| 10:48:46.5 **HOT-1** | oops. thank you. | | |
| | | 10:50:07.2 **NYC** | Delta ten eighty six maintain two ten or greater. |
| | | 10:50:10.3 **RDO-2** | maintain two ten or greater. Delta ten eighty six. |

| Time and Source | Intra-Aircraft Communication | Time and Source | Over-the-Air Communication |
|---|---|---|---|
| 10:50:39.0 **CAM** | [sound similar to altitude alert] | | |
| 10:51:27.2 **HOT** | [sound similar to IGDI Morse code identifier] | | |
| 10:51:34.0 **HOT** | [sound similar to IGDI Morse code identifier] | | |
| 10:51:42.1 **HOT** | [sound similar to IGDI Morse code identifier] | | |
| 10:51:50.9 **HOT** | [sound similar to IGDI Morse code identifier] | | |
| | | 10:51:53.9 **NYC** | Delta ten eighty six turn right heading zero four zero. |
| 10:51:58.5 **HOT-1** | right heading zero four— | | |
| | | 10:51:59.0 **RDO-2** | right heading zero four zero. Delta ten eighty six. |
| 10:52:01.4 **HOT-2** | good ID both sides. | | |
| 10:52:06.0 **HOT-1** | where is everybody? | | |
| 10:52:31.9 **HOT-1** | I think she's gonna take us— | | |
| 10:52:32.9 **HOT-2** | yeah she's— yeah. yes sir. | | |

| Time and Source | Intra-Aircraft Communication | Time and Source | Over-the-Air Communication |
|---|---|---|---|
| 10:52:41.4 **HOT-1** | put twenty seven five in here. | | |
| 10:52:46.1 **HOT-1** | two thirty two...one eighty five...one fifty seven...one thirty one— one forty four rather. | | |
| | | 10:52:50.8 **NYC** | attention all aircraft. information quebec is now current. advise quebec. |
| 10:52:56.3 **HOT-1** | thirty one five thirty six | | |
| 10:53:03.1 **HOT-2** | roger. briefed crosschecked. | | |
| 10:53:04.4 **HOT-1** | you #. | | |
| 10:53:07.6 **HOT-1** | I'm gonna have to call and talk— and have a heart to heart with our dispatcher. | | |
| 10:53:15.0 **HOT-1** | if it's not closed then why were we holding? | | |
| | | 10:53:16.9 **NYC** | Delta ten eighty six descend and maintain three thousand. |
| 10:53:17.5 **HOT-2** | yeah. | | |
| 10:53:17.7 **HOT-1** | they were clearing it. | | |

| Time and Source | Intra-Aircraft Communication | Time and Source | Over-the-Air Communication |
|---|---|---|---|
| | | 10:53:20.2 **RDO-2** | descend to three thousand Delta ten eighty six. |
| 10:53:21.9 **HOT-1** | three thousand. | | |
| 10:53:22.9 **HOT-2** | three thousand. altitude's armed. vert speed. | | |
| 10:53:24.9 **HOT-1** | it's uh...descending and armed. | | |
| 10:53:38.4 **CAM** | [sound similar to altitude alert] | | |
| 10:54:02.6 **CAM** | [sound similar to stab trim in motion] | | |
| 10:54:12.4 **HOT-2** | we have quebec. | | |
| 10:54:24.2 **HOT-1** | three zero one two. | | |
| 10:54:25.1 **HOT-2** | thirty twelve on the meter. | | |
| 10:54:26.4 **HOT-1** | is crosschecked. | | |
| 10:54:27.3 **HOT-2** | crosschecked. | | |
| | | 10:54:37.3 **NYC** | Delta ten eighty six turn left heading three four zero. reduce speed to one eight zero. |

| Time and Source | Intra-Aircraft Communication | Time and Source | Over-the-Air Communication |
|---|---|---|---|
| | | 10:54:41.4 **RDO-2** | left turn three four zero. slow to a hundred eighty knots. Delta ten eighty six. we have quebec. |
| | | 10:54:45.3 **NYC** | thank you. |
| 10:54:48.7 **HOT-1** | flaps eleven. | | |
| 10:54:50.0 **HOT-2** | flaps to eleven. | | |
| 10:55:33.9 **HOT-1** | wonder who reported braking action good? that's another concern of mine. | | |
| 10:55:37.4 **HOT-2** | it was United. he said United did. | | |
| 10:55:41.7 **HOT-1** | what kind of airplane was he? | | |
| | | 10:55:46.6 **NYC** | Delta ten eighty six turn left heading two niner zero. |
| | | 10:55:49.4 **RDO-2** | left two nine zero. Delta ten eighty six. |
| 10:56:06.0 **CAM** | [sound similar to stab trim in motion] | | |
| 10:56:08.1 **INT-3** | @ one left. | | |

| Time and Source | Intra-Aircraft Communication | Time and Source | Over-the-Air Communication |
|---|---|---|---|
| 10:56:09.2 **INT-1** | hey @ it's @ @ make one more swing through the galley and make sure everything is secured. | | |
| 10:56:14.8 **INT-3** | I'm sorry I can barely hear you. | | |
| 10:56:16.4 **HOT-2** | yeah she's # crazy. | | |
| 10:56:17.9 **INT-1** | can you hear me now? | | |
| 10:56:19.0 **INT-3** | yeah. | | |
| 10:56:19.4 **INT-1** | make one more swing through the galley and make sure everything's really battened down. we're gonna be using max autobrakes cause of the snow. | | |
| 10:56:25.0 **INT-3** | okay well we're all strapped down. I mean we've already done our walkthrough. | | |
| 10:56:28.3 **INT-1** | okay. | | |
| 10:56:28.8 **INT-3** | cleaned up everything. we're already in our seats. | | |
| 10:56:29.1 **INT-1** | so long as you're okay. yeah that's fine. | | |
| | | 10:56:31.4 **NYC** | Delta ten eighty six turn left heading two five zero. |

| Time and Source | Intra-Aircraft Communication | Time and Source | Over-the-Air Communication |
|---|---|---|---|
| 10:56:31.6 **INT-3** | okay. | | |
| 10:56:32.0 **INT-1** | it'll be a little— it'll be a while before we land but that's fine. | | |
| | | 10:56:34.3 **RDO-2** | left turn two five zero. Delta ten eighty six. |
| 10:56:35.4 **INT-1** | okay. | | |
| 10:56:37.3 **HOT-2** | two fifty on the heading. | | |
| 10:56:38.1 **HOT-1** | two fifty. | | |
| 10:56:48.6 **HOT-1** | quit your whining @. | | |
| 10:56:52.9 **HOT-2** | yeah she's not the sharpest tool. | | |
| 10:56:55.4 **HOT-1** | what's that? | | |
| 10:56:56.0 **HOT-2** | she's not the sharpest one in the shed. | | |
| 10:57:10.3 **HOT** | [sound similar to IGDI Morse code identifier] | | |
| 10:57:21.6 **HOT-2** | it's gonna be awesome when you hear the— the coffee pots come flying out. | | |

| Time and Source | Intra-Aircraft Communication | Time and Source | Over-the-Air Communication |
|---|---|---|---|
| | | 10:57:30.8 **NYC** | Delta ten eighty six turn left heading two two zero. |
| | | 10:57:33.7 **RDO-2** | left turn two two zero. Delta ten eighty six. |
| 10:57:36.1 **HOT-1** | let's go flaps fifteen. | | |
| 10:57:37.2 **HOT-2** | fifteen. | | |
| | | 10:57:38.3 **NYC** | attention all aircraft. regional jet reported braking action good. |
| 10:57:41.6 **HOT-1** | regional. | | |
| 10:57:41.9 **HOT-2** | RJ good. | | |
| | | 10:57:47.3 **NYC** | Delta ten eighty six turn left heading one eight zero. |
| | | 10:57:49.8 **RDO-2** | left one eight zero. Delta ten eighty six. |
| | | 10:58:18.5 **NYC** | Delta ten eighty six turn left heading one six zero. join the localizer. |
| | | 10:58:22.6 **RDO-2** | left turn one eight zero. join the localizer. Delta ten eighty six. |

| Time and Source | Intra-Aircraft Communication | Time and Source | Over-the-Air Communication |
|---|---|---|---|
| 10:58:25.8 **HOT-1** | localizer's armed. | | |
| 10:58:26.0 **HOT-2** | approaching inbound course. | | |
| | | 10:58:41.3 **NYC** | Delta ten eighty six over PAYMI cleared ILS runway one three approach. |
| 10:58:44.3 **HOT-2** | locs— | | |
| | | 10:58:45.1 **RDO-2** | cleared ILS runway one three approach. Delta ten eighty six. |
| 10:58:48.3 **HOT-2** | loc is alive and locs captured. | | |
| 10:58:50.5 **HOT-1** | we'll intercept it at three thousand here. | | |
| 10:58:53.3 **HOT-2** | sure. glideslope's alive as well. | | |
| 10:58:54.5 **HOT-1** | let's see...go with a one thirty... | | |
| 10:59:05.4 **HOT-2** | glideslope's captured. | | |
| 10:59:06.7 **HOT-1** | thank you. | | |

| Time and Source | Intra-Aircraft Communication | Time and Source | Over-the-Air Communication |
|---|---|---|---|
| 10:59:09.4 **HOT-1** | let's go gear down. | | |
| 10:59:11.0 **HOT-2** | gear is comin' down. | | |
| | | 10:59:12.3 **NYC** | Delta ten eighty six tower one one eight seven. RVR is greater than six thousand. rollout four thousand. have a good day. |
| 10:59:12.3 **CAM** | [sound similar to landing gear deployment] | | |
| | | 10:59:17.5 **RDO-2** | switch to tower Delta ten eighty six. good day. |
| 10:59:24.1 **CAM** | [sound of click] | | |
| | | 10:59:24.4 **RDO-2** | tower Delta ten eighty six joining you ILS runway one three. |
| 10:59:30.1 **HOT-1** | flaps forty. landing checklist. | | |
| 10:59:31.6 **HOT-2** | speed checks good. | | |
| 10:59:32.3 **CAM** | [sound similar to flap handle movement] | | |

| Time and Source | Intra-Aircraft Communication | Time and Source | Over-the-Air Communication |
|---|---|---|---|
| | | 10:59:34.0 **LGA** | and Delta ten eighty six LaGuardia Tower. uh winds zero three zero at niner. runway one three cleared to land. braking action reported good by an Airbus and then a regional jet. there will be a departure on runway four prior to your arrival. runway one three RVR touchdown greater than six thousand. rollout three thousand five hundred. |
| 10:59:38.2 **CAM** | [sound of four clicks] | | |
| 10:59:43.9 **CAM** | [sound similar to stab trim in motion] | | |
| | | 10:59:51.7 **RDO-2** | copy all. cleared to land on runway one three. Delta ten eighty six. |
| 10:59:54.4 **HOT-1** | alright ask him one more time for a wind check. I'm showing a pretty good tailwind here. eleven knots. | | |
| 11:00:02.3 **HOT-1** | when you get a chance. | | |
| 11:00:02.9 **HOT-2** | yeah uh do you mind if we wrap landing checklist? | | |
| 11:00:05.0 **HOT-1** | for landing. got it. go ahead. | | |
| 11:00:05.1 **CAM** | [sound similar to stab trim in motion] | | |
| 11:00:06.6 **HOT-2** | landing gear? | | |

| Time and Source | Intra-Aircraft Communication | Time and Source | Over-the-Air Communication |
|---|---|---|---|
| 11:00:07.5 **HOT-1** | down three green. pressures and quantities are normal. | | |
| 11:00:08.2 **HOT-2** | down...three green. flaps slats? | | |
| 11:00:11.4 **HOT-1** | I've got forty forty. land. | | |
| 11:00:12.6 **CAM** | [sound of click] | | |
| 11:00:13.6 **HOT-2** | forty forty land. spoilers? | | |
| 11:00:15.3 **HOT-1** | spoilers are armed. | | |
| 11:00:16.2 **HOT-2** | armed. ignitions off. autobrakes are armed. maximum. uh annunciator panel is checked. landing checklist complete. | | |
| 11:00:28.6 **HOT-2** | alright. | | |
| | | 11:00:31.2 **RDO-2** | wind check. |
| | | 11:00:32.2 **LGA** | wind zero two zero at one zero. |
| 11:00:33.9 **HOT-2** | zero two zero at one zero. | | |
| 11:00:36.3 **HOT-1** | geez. | | |

| Time and Source | Intra-Aircraft Communication | Time and Source | Over-the-Air Communication |
|---|---|---|---|
| 11:00:38.7 **HOT-1** | yeah. | | |
| 11:00:40.9 **HOT-1** | okay. | | |
| 11:00:41.2 **HOT-2** | we're all counting on you. alright. | | |
| 11:00:45.1 **HOT-1** | gear. flaps forty. spoilers. maximum autobrakes and armed. | | |
| 11:00:45.1 **HOT-2** | dim dim dim dim. tail deice is on. | | |
| 11:00:50.0 **HOT-1** | thanks. | | |
| 11:00:50.9 **CAM** | [sound of click] | | |
| 11:01:02.6 **CAM** | one thousand. [automated voice] | | |
| 11:01:04.3 **HOT-2** | cleared to land. missed approach altitude is set. | | |
| 11:01:06.6 **HOT-1** | thanks. | | |
| 11:01:11.1 **CAM** | [sound similar to stab trim in motion] | | |
| 11:01:39.3 **CAM** | five hundred. [automated voice] | | |

| Time and Source | Intra-Aircraft Communication | Time and Source | Over-the-Air Communication |
|---|---|---|---|
| 11:01:39.8 **HOT-1** | gear. flaps forty. spoilers. maximum brakes. | | |
| 11:01:41.2 **HOT-2** | very well. | | |
| 11:01:51.4 **HOT-1** | approach lights are in sight. | | |
| 11:01:53.0 **HOT-2** | very good. | | |
| 11:01:53.5 **HOT-1** | we're gonna continue. | | |
| 11:01:58.8 **HOT-1** | runway's in sight. | | |
| 11:01:59.3 **HOT-2** | approaching minimums. roger. | | |
| 11:02:01.5 **HOT-1** | everything's off. runway is in sight. | | |
| 11:02:08.7 **CAM** | one hundred. [automated voice] | | |
| 11:02:11.6 **CAM** | fifty. [automated voice] | | |
| 11:02:12.6 **CAM** | forty. [automated voice] | | |
| 11:02:13.2 **CAM** | thirty. [automated voice] | | |

| Time and Source | Intra-Aircraft Communication | Time and Source | Over-the-Air Communication |
|---|---|---|---|
| 11:02:13.8 **CAM** | twenty. [automated voice] | | |
| 11:02:15.0 **CAM** | ten. [automated voice] | | |
| 11:02:15.9 **CAM** | [sound similar to main gear touchdown] | | |
| 11:02:17.9 **CAWS** | [sound of beep] [CAWS configuration warning] | | |
| 11:02:17.9 **CAM** | [sound of click followed by mechanical noise] | | |
| 11:02:18.3 **CAWS** | [sound of beep] [CAWS configuration warning] | | |
| 11:02:18.5 **HOT-2** | spoilers up. | | |
| 11:02:18.9 **CAWS** | speedbrakes.[automated voice. CAWS configuration warning] | | |
| 11:02:19.4 **CAM** | [sound similar to nose gear touchdown] | | |
| 11:02:20.9 **HOT-2** | two in reverse. | | |
| 11:02:22.2 **HOT-2** | one ten. | | |
| 11:02:23.7 **HOT-2** | out of reverse. | | |

| Time and Source | Intra-Aircraft Communication | Time and Source | Over-the-Air Communication |
|---|---|---|---|
| 11:02:24.5 **HOT-2** | come out of reverse. | | |
| 11:02:25.2 **HOT-2** | come out of reverse. [louder] | | |
| 11:02:27.2 **HOT-1** | #. | | |
| 11:02:27.5 **HOT-2** | #. | | |
| 11:02:27.8 **CAM** | [rumbling noise increases] | | |
| 11:02:28.6 **HOT-1** | #. | | |
| 11:02:29.1 **CAM** | [sound of rumbling] | | |
| 11:02:32.0 **CAM** | [sounds of increased rumbling noise lasts 19.4 seconds] | | |
| 11:02:33.1 **CAWS** | [sound of CAWS landing gear configuration warning horn lasts until end of recording] | | |
| 11:02:40.4 **CAM-?** | (idle or out of) reverse. (idle or out of) reverse. | | |
| 11:02:43.2 **CAM** | [sound of louder scraping lasting 8.3 seconds] | | |
| | | 11:02:45.1 **LGA** | Delta ten eighty six? |

| Time and Source | Intra-Aircraft Communication | Time and Source | Over-the-Air Communication |
|---|---|---|---|
| 11:02:47.6 **CAM-?** | #. | | |
| 11:02:48.0 **CAM-?** | #. | | |
| 11:02:49.4 **CAM-?** | #. | | |
| 11:02:51.6 **CAM** | [sound of scraping noise ends] | | |
| | | 11:02:51.8 **LGA** | Delta ten eighty six? |
| 11:02:53.5 **CAM-?** | #. | | |
| 11:02:54.3 **END OF RECORDING** **END OF TRANSCRIPT** | | | |

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